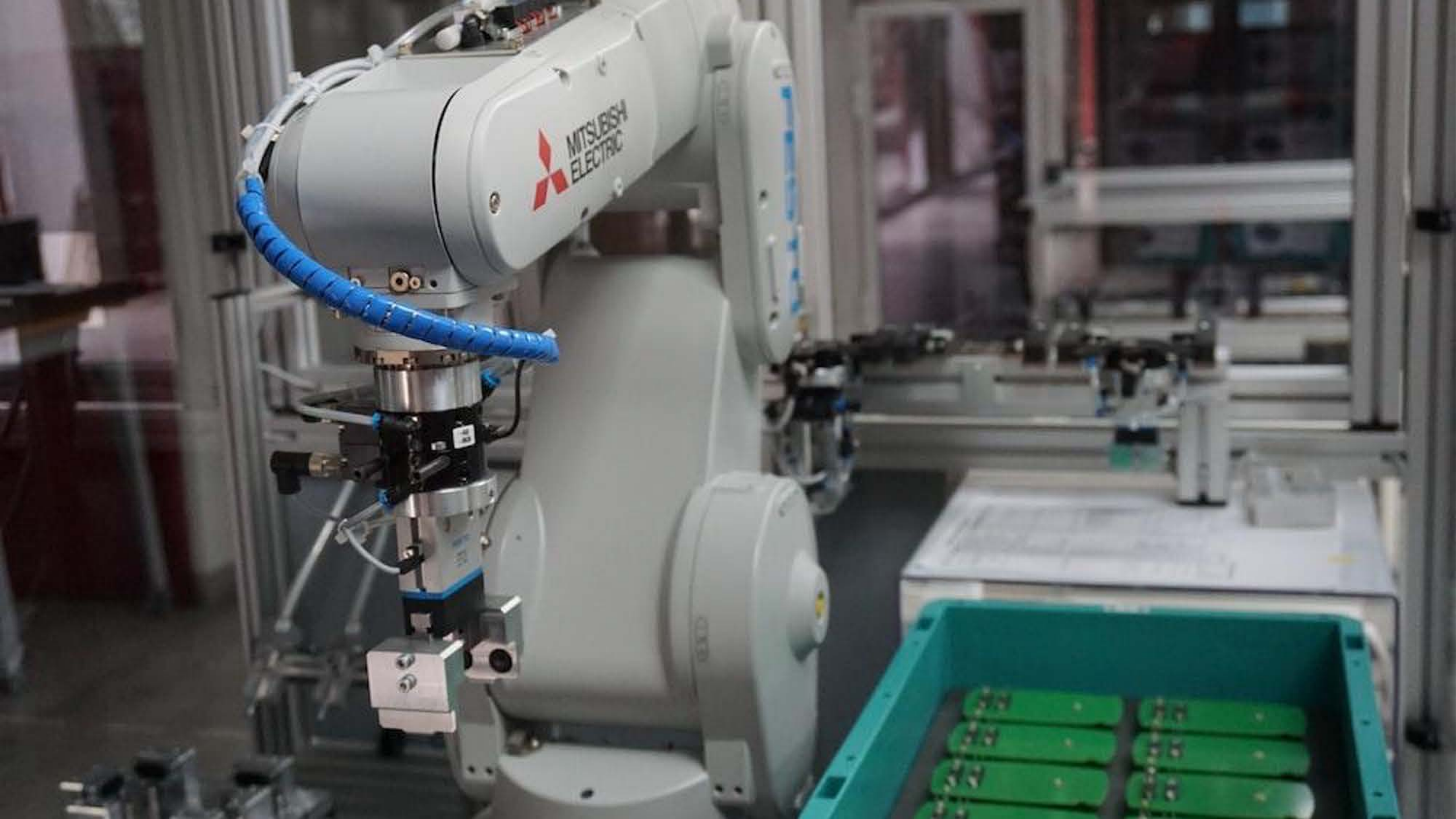
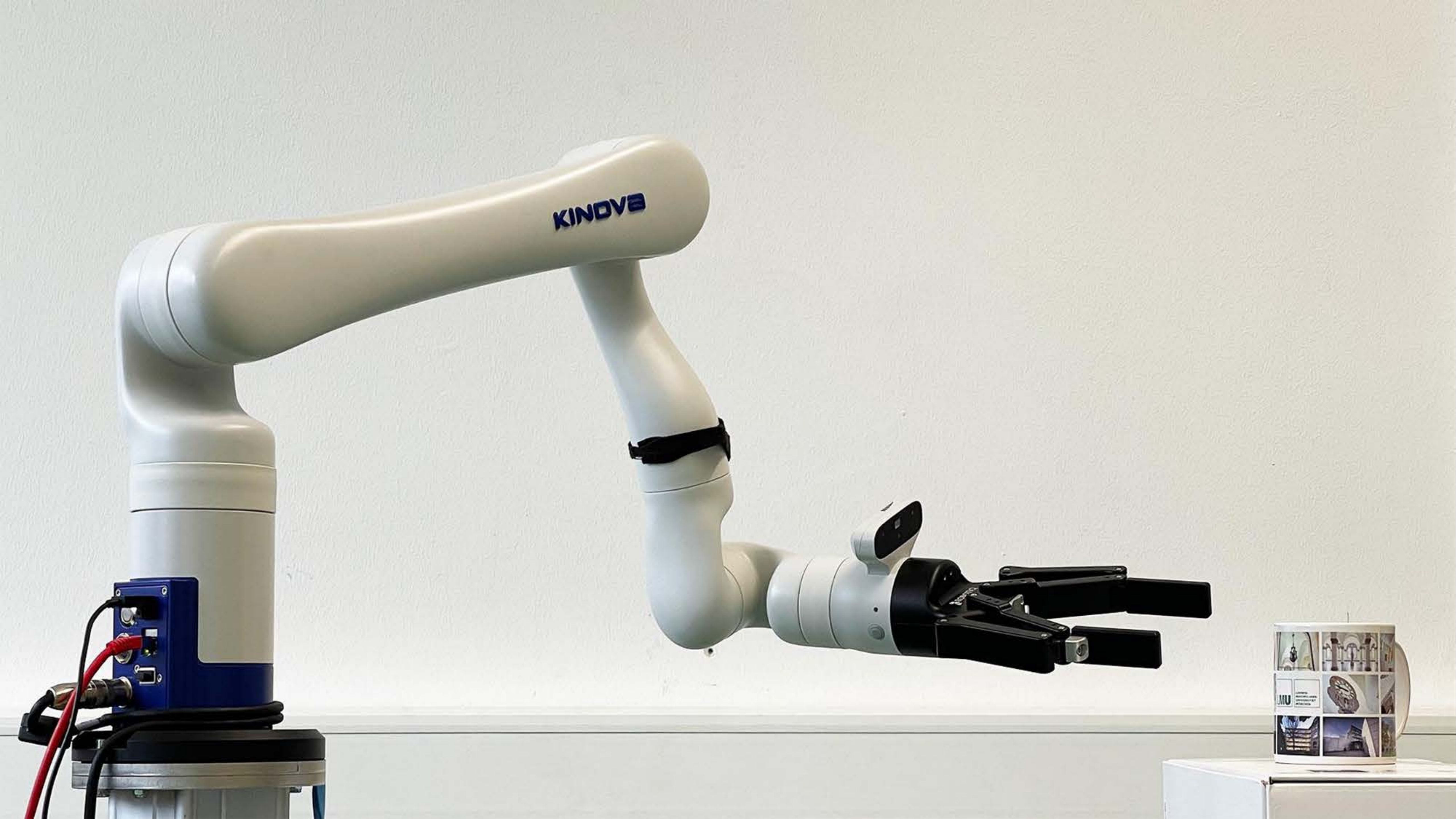
Introduction to Intelligent User Interfaces

Introduction into Human-Robot Interaction


MITSUBISHI
ELECTRIC

https://www.bostondynamics.com/resources/blog/how-much-radiation-can-spot-withstand


KINOVA

Carl Oechsner, Sven Mayer, Andreas Butz (2022) Challenges and Opportunities of Cooperative Robots as Cooking Appliances. In Proc. of the 2022 Workshop on Engaging with Automation.

Human-Robot Interaction != Robotics

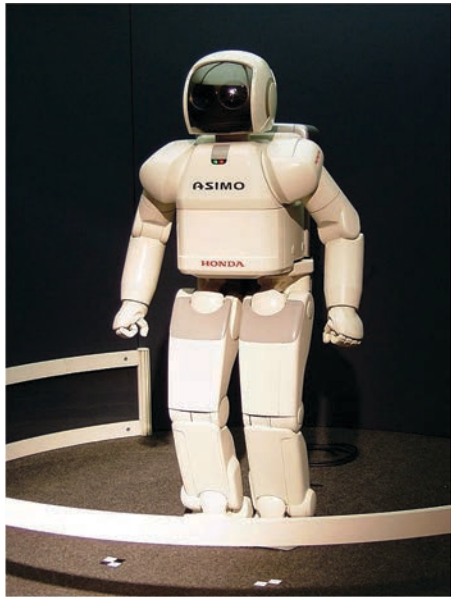
HRI	Robotics
Interaction, communication, and collaboration between humans and robots in the social world	Creation, design, construction, and operation of robots

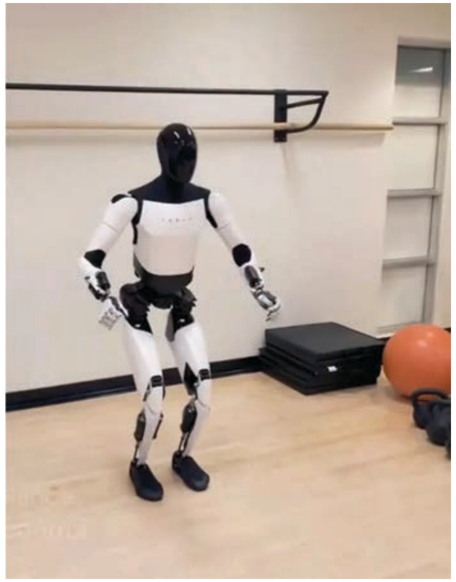
Human-Robot Interaction

- HRI is a subfield of HCI, which includes a physical, embodied entity - robots.
- Challenges of HRI are often times more diverse due to the inclusion of physical movements, sensors, and the need to understand human social cues.
- Main differences:
  - **Interaction Entity**: Robotic systems instead of traditional computing devices
  - **Communication Medium**: verbal communication, gestures, physical manipulation, AR instead of GUIs, touchscreens, and keyboards & mice
  - **Purpose**: Emphasis on integration of robots into human environments. Aim is to create effective, safe, and intuitive interactions between humans and robots
  - **Scope**: Applied domains like healthcare, manufacturing, entertainment, and domestic settings in shared spaces
- HRI focuses on developing robots that can interact with people in various everyday environments.

Advances in Robotics enable HRI Research

- Humanoid Robots
- Sensory enhancements
- Collaborative Robots (Cobots)
- Better build quality
- Advances in AI
  - Natural language processing
  - Gesture Recognition





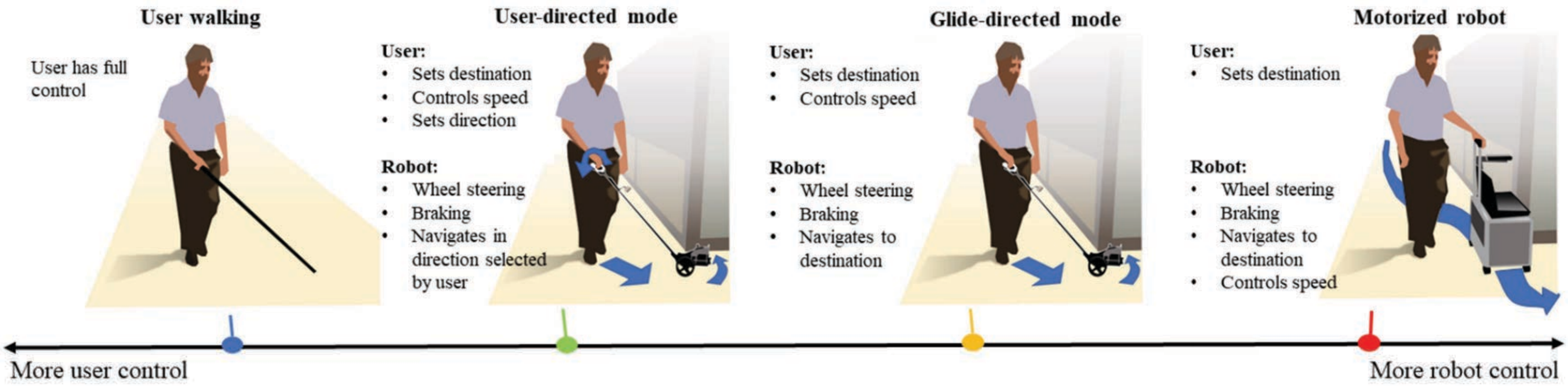
Domains of HRI Research

- Accessibility
- Supporting Elderly
- Educating Children
- Supporting Communication
- Supporting with Household Tasks

Accessibility

Exploring Levels of Control for a Navigation Assistant for Blind Travelers

- Robot guiding blind people while walking
- Different levels of user and robot control
- Users prefer different levels of autonomy

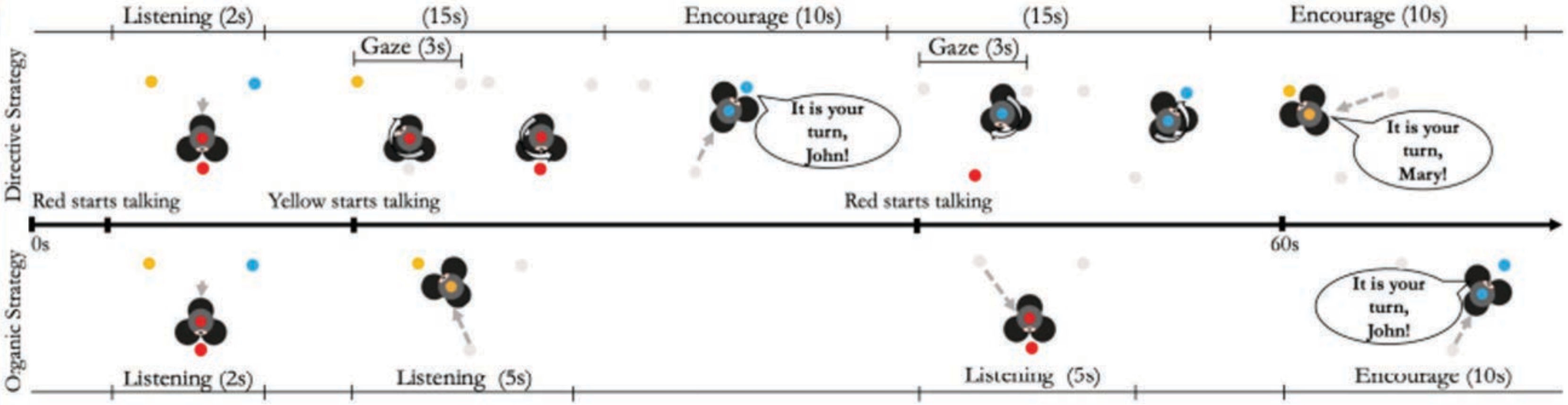


Ranganeni, V., Sinclair, M., Ofek, E., Miller, A., Campbell, J., Kolobov, A., & Cutrell, E. (2023, March). Exploring Levels of Control for a Navigation Assistant for Blind Travelers. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 4-12).

Accessibility

"The Robot Made Us Hear Each Other": Fostering Inclusive Conversations among Mixed-Visual Ability Children

- Robot as mediator in conversations between children
- Encouraging the least participative child to speak
- Fosters inclusion in mixed-visual ability group conversations



Neto, I., Correia, F., Rocha, F., Piedade, P., Paiva, A., & Nicolau, H. (2023, March). The Robot Made Us Hear Each Other: Fostering Inclusive Conversations among Mixed-Visual Ability Children. In *Proceedings of the 2023 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 13-23).

Supporting Elderly People

- Socially Assistive Robots to support elderly
- Humanoid robots (e.g., Pepper) can work in a care home, but moderating person is needed
- Elderly residents are positively engaged in robot trainings sessions

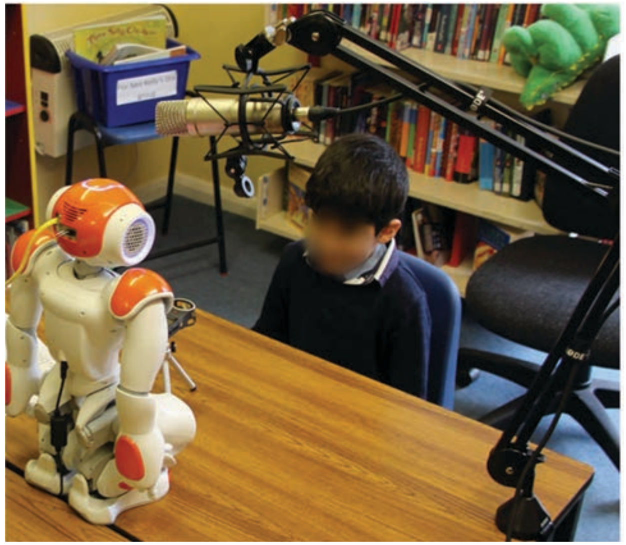
Figure 1: Group setting with the Pepper Robot

Fig. 1. *Exercise setup with user and robot facing each other.*

Carros, F., Meurer, J., Löffler, D., Unbehaun, D., Matthies, S., Koch, I., ... & Wulf, V. (2020, April). Exploring human-robot interaction with the elderly: results from a ten-week case study in a care home. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (pp. 1-12).
Fasola, J., & Mataric, M. J. (2012). Using socially assistive human–robot interaction to motivate physical exercise for older adults. *Proceedings of the IEEE*, *100*(8), 2512-2526.

Supporting & Educating Children

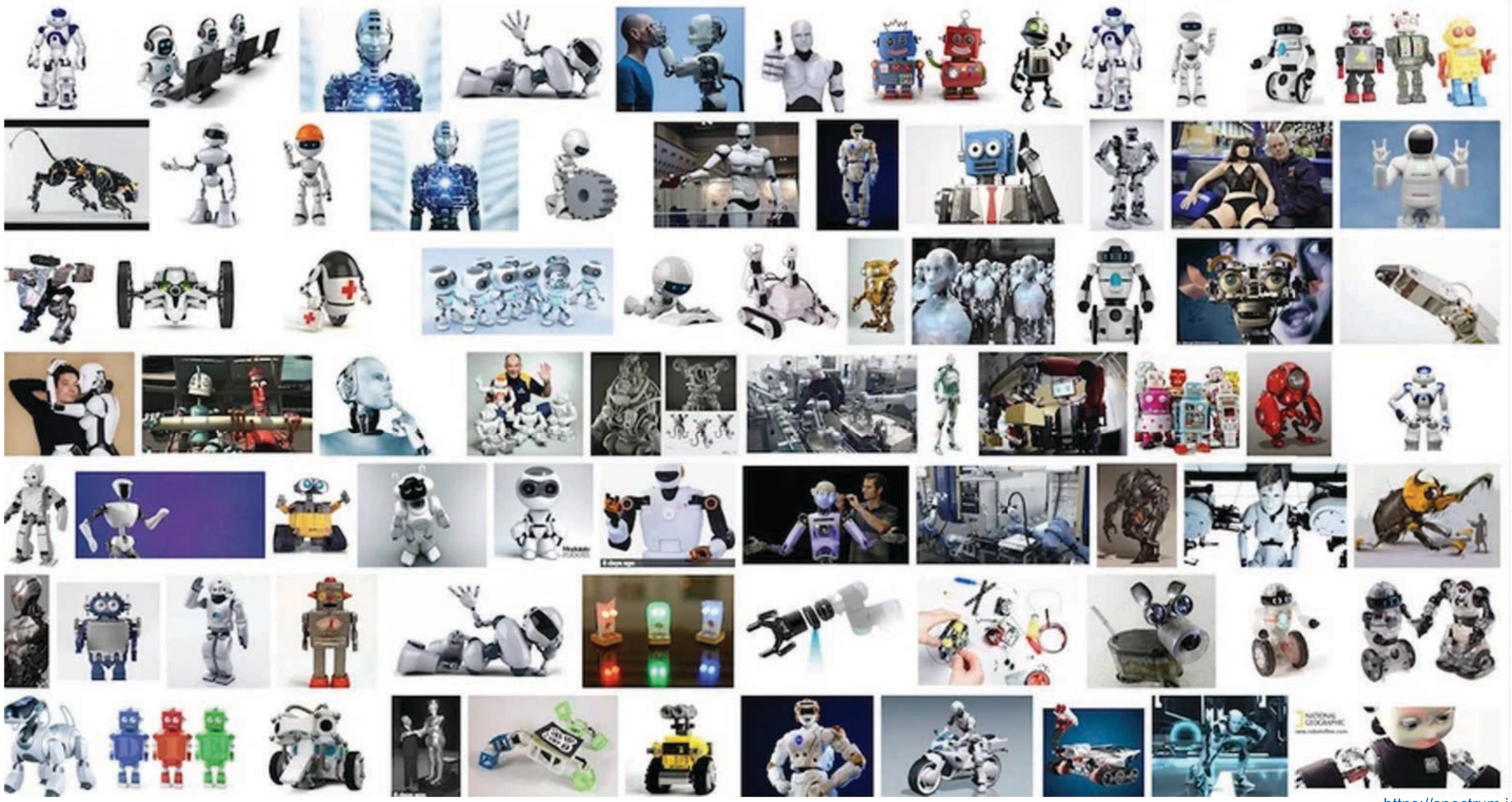
- NAO robot used for applied studies to train child speech and fostering interaction



Baxter, P., Belpaeme, T., Canamero, L., Cosi, P., Demiris, Y., Enescu, V., ... & Wood, R. (2011, March). Long-term human-robot interaction with young users. In IEEE/ACM human-robot interaction 2011 conference (robots with children workshop) (Vol. 80). IEEE/ACM.
Kennedy, J., Lemaignan, S., Montassier, C., Lavalade, P., Irfan, B., Papadopoulos, F., ... & Belpaeme, T. (2017, March). Child speech recognition in human-robot interaction: evaluations and recommendations. In Proceedings of the 2017 ACM/IEEE international conference on human-robot interaction (pp. 82-90).

Robots in Domestic Settings

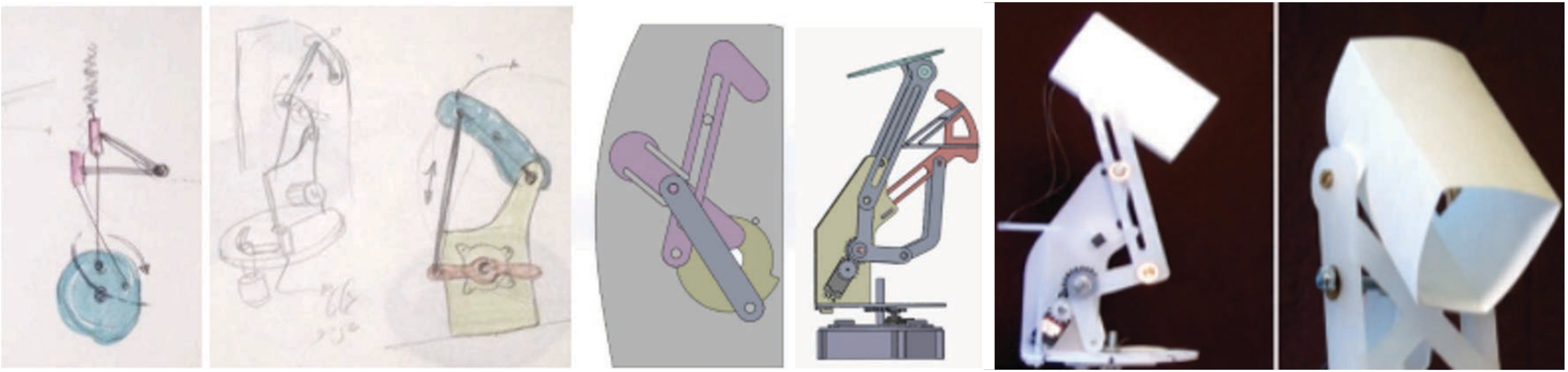
What is a Robot?



https://spectrum.ieee.org/robots-and-racism

Humanoid Robots

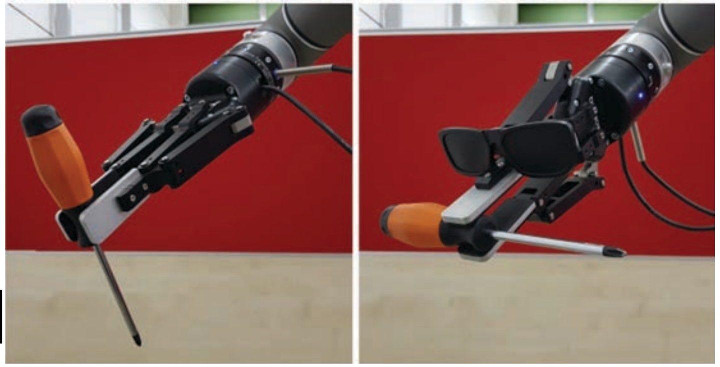
Non-humanoid Robots



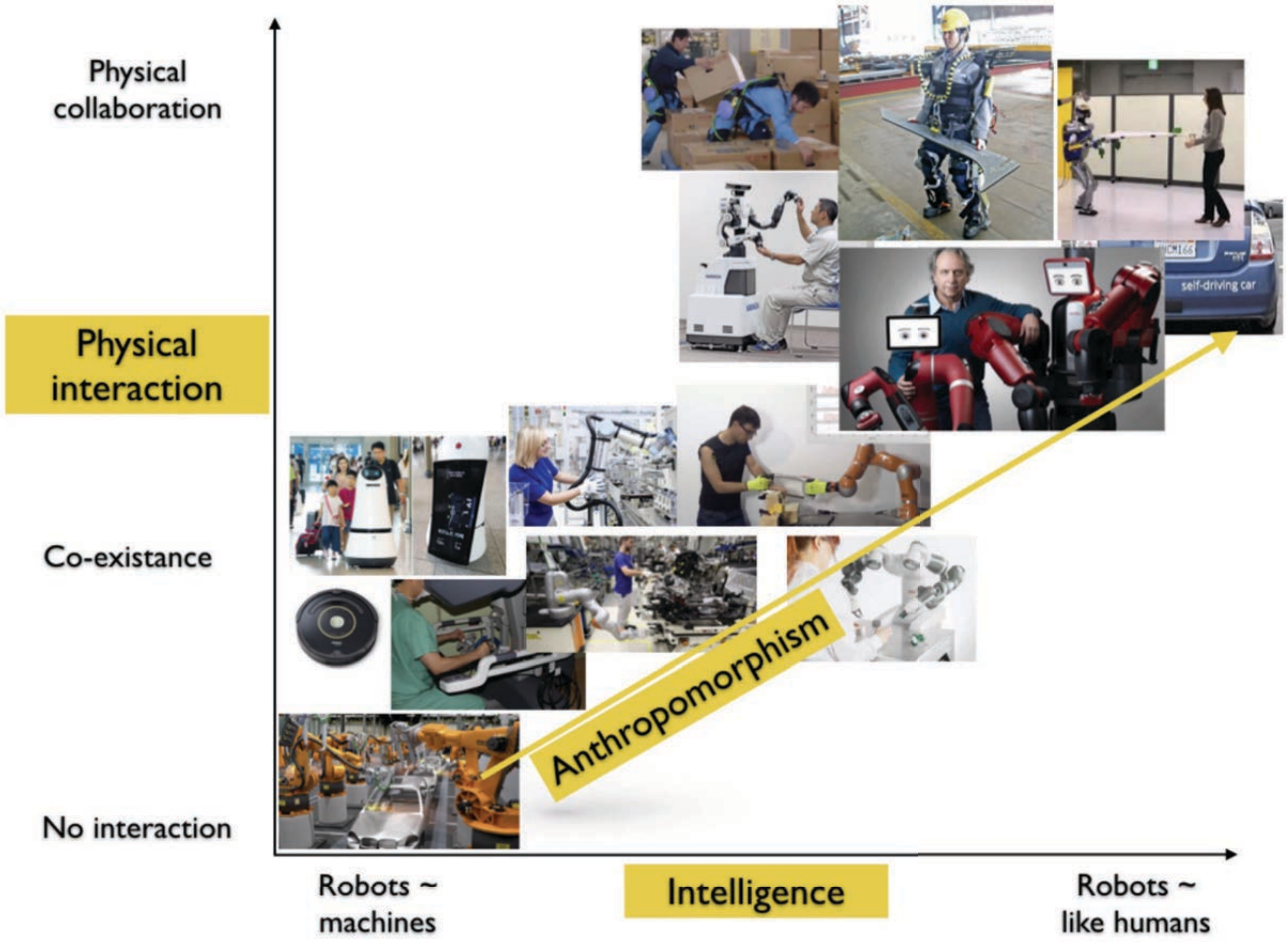
Hoffman, G., Zuckerman, O., Hirschberger, G., Luria, M., & Shani Sherman, T. (2015, March). Design and evaluation of a peripheral robotic conversation companion. In *Proceedings of the tenth annual ACM/IEEE international conference on human-robot interaction* (pp. 3-10).

Anthropomorphism

- Definition: *Anthropomorphism is the idea that an object has feelings or characteristics like those of a human being. In other words, it means that humans regard the object as a person to communicate with, and moreover try to read its mind. [1]*
- Gradient in how many human traits we can describe a machine with
- How to Measure: Godspeed Questionnaire [2]
- Already minor adjustments can increase the levels of perceived anthropomorphism of non-humanoid robots [3]



[1] Ono, T.; Imai, M.; Ishiguro, H. (2000) Anthropomorphic communications in the emerging relationship between humans and robots. Proceedings 9th IEEE International Workshop on Robot and Human Interactive Communication. IEEE RO-MAN 2000.. https://doi.org/10.1109/roman.2000.892519
[2] Bartneck, C., Croft, E., Kulic, D. & Zoghbi, S. (2009) Measurement instruments for the anthropomorphism, animacy, likeability, perceived intelligence, and perceived safety of robots. International Journal of Social Robotics, https://doi.org/10.1007/s12369-008-0001-3
[3] Terzioğlu, Y., Mutlu, B., & Şahin, E. (2020, March). Designing social cues for collaborative robots: the role of gaze and breathing in human-robot collaboration. In Proceedings of the 2020 ACM/IEEE international conference on human-robot interaction (pp. 343-357).



Ivaldi, S. (2018). Intelligent human-robot collaboration with prediction and anticipation. ERCIM news.

Trust in Human-Robot Interaction

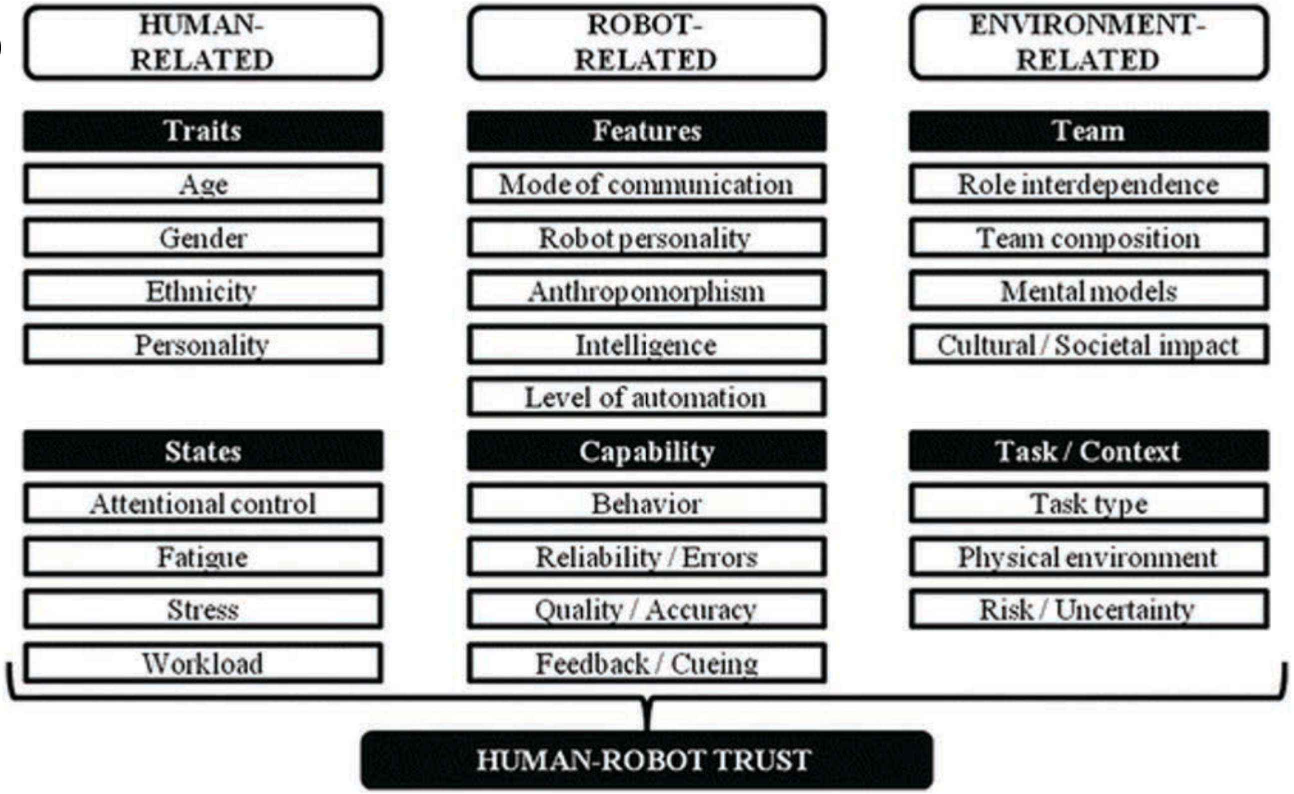
The Psychology of Interpersonal Trust

"to believe that someone is good and honest and will not harm you, or that something is safe and reliable"

https://dictionary.cambridge.org/dictionary/english/trust

Trust in Human-Robot Interaction

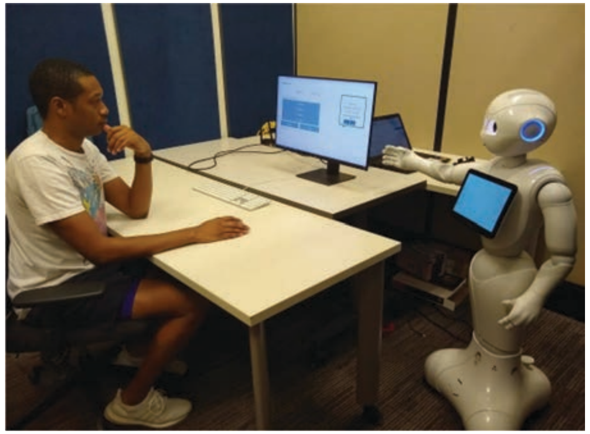
- What's the difference between human-human trust and trust in **computers/rob**



Schaefer, K. E. (2016). Measuring trust in human robot interactions: Development of the "trust perception scale-HRI". In Robust intelligence and trust in autonomous systems (pp. 191-218). Boston, MA: Springer US.

Trust and Anthropomorphism

- Higher levels of anthropomorphism lead to higher level of trust [2]
- Appearance and behaviour of robot can lead to overestimation of its functionality [1]
- Perceived anthropomorphism is not only limited to the appearance of the robot but also its behaviour [3]
- Users often assume and expect a humanoid robot can do everything another human could do based on its appearance [3]



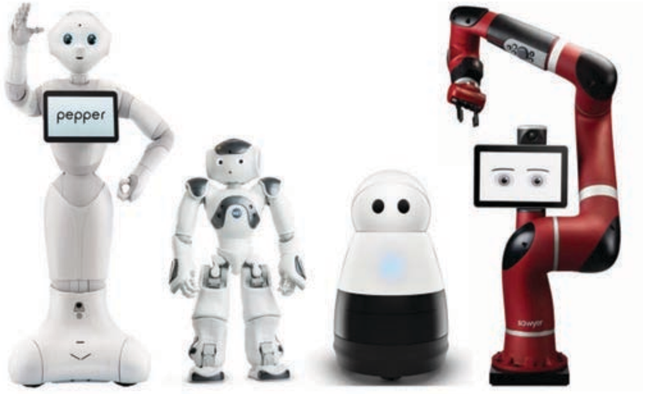


Figure 3: Robots used in study: (From left to right) Pepper, Nao, Kuri, and Sawyer

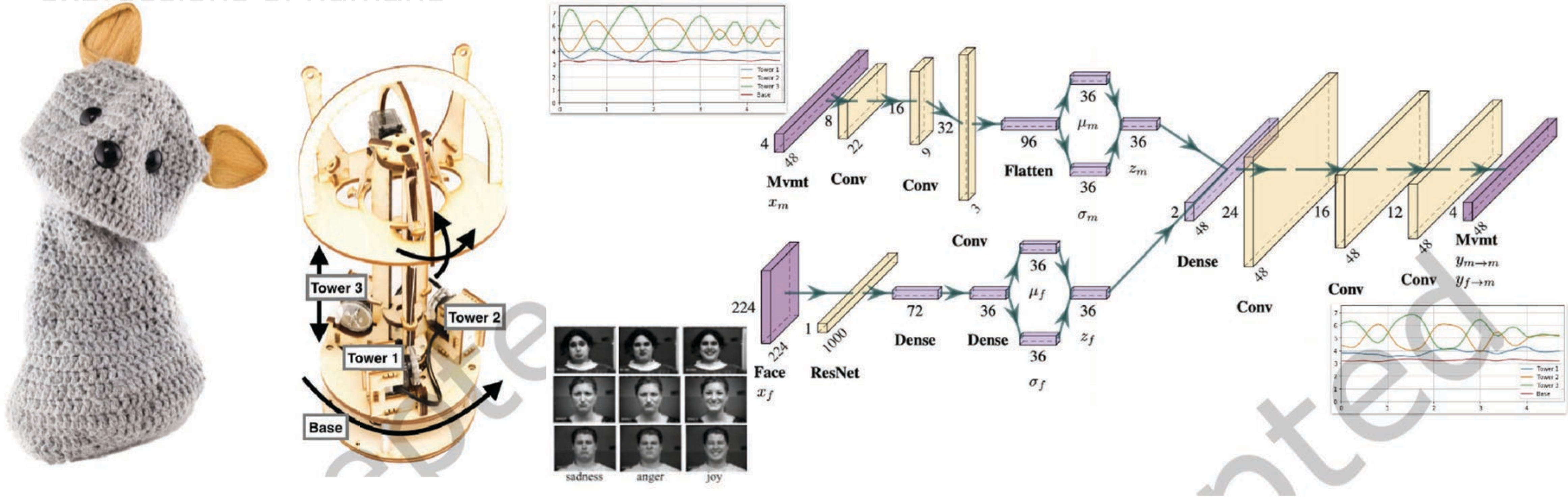
[1] Sharkey, A., & Sharkey, N. (2021). We need to talk about deception in social robotics!. Ethics and Information Technology, 23, 309-316.
[2] Natarajan, M., & Gombolay, M. (2020, March). Effects of anthropomorphism and accountability on trust in human robot interaction. In Proceedings of the 2020 ACM/IEEE international conference on human-robot interaction (pp. 33-42).
[3] Złotowski, J., Proudfoot, D., Yogeeswaran, K., & Bartneck, C. (2015). Anthropomorphism: opportunities and challenges in human–robot interaction. *International journal of social robotics*, *7*, 347-360.

How can we use this Information? How can robots communicate their intents?

Understandability of Robot Expressions

Face2Gesture

- Automatically generate and map affective robot movements to emotional facial expressions of humans

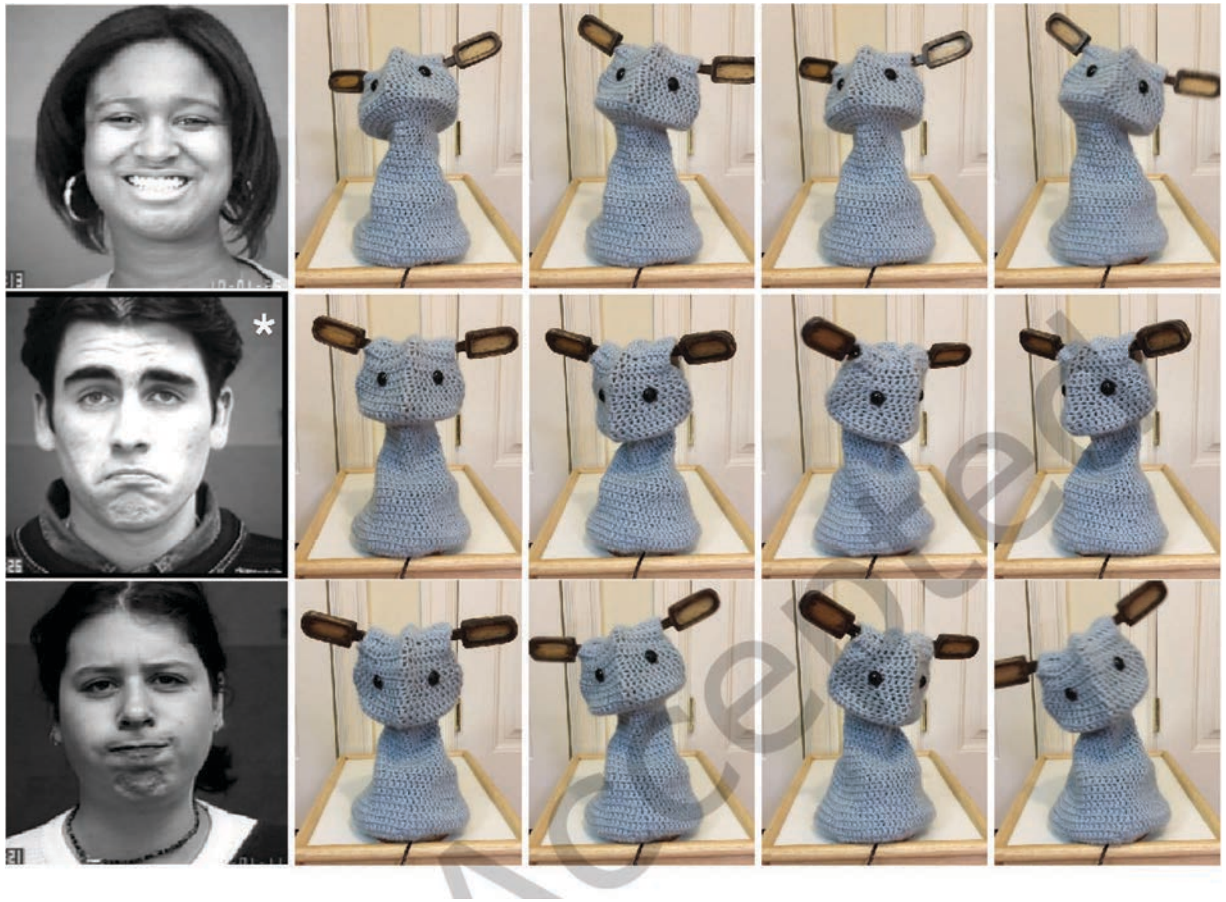


Suguitan, M., DePalma, N., Hoffman, G., & Hodgins, J. (2023). Face2Gesture: Translating Facial Expressions Into Robot Movements Through Shared Latent Space Neural Networks. *ACM Transactions on Human-Robot Interaction*.

Understandability of Robot Expressions

Face2Gesture

Subjective user evaluation reveals that users could recognize happy and sad movements, but not angry



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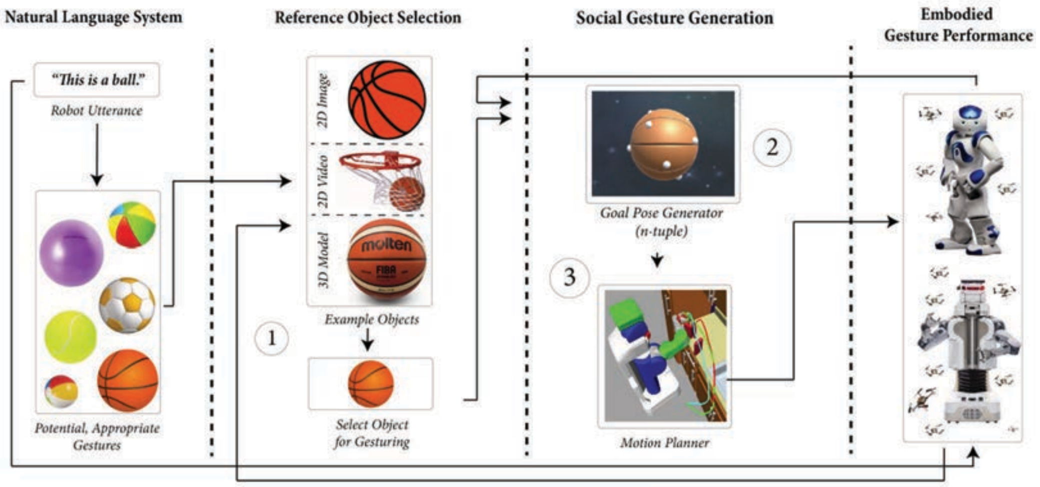
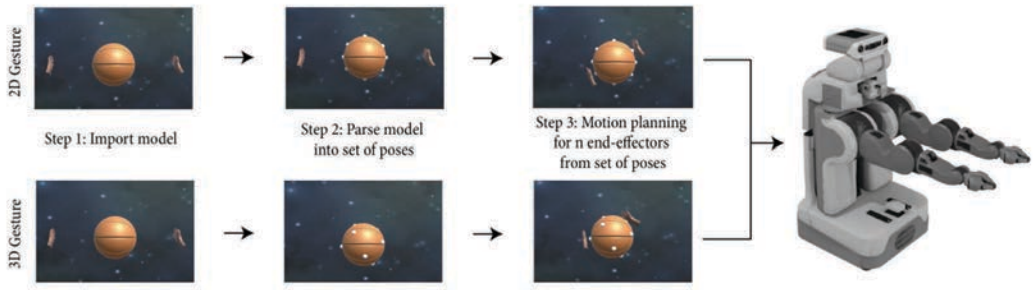
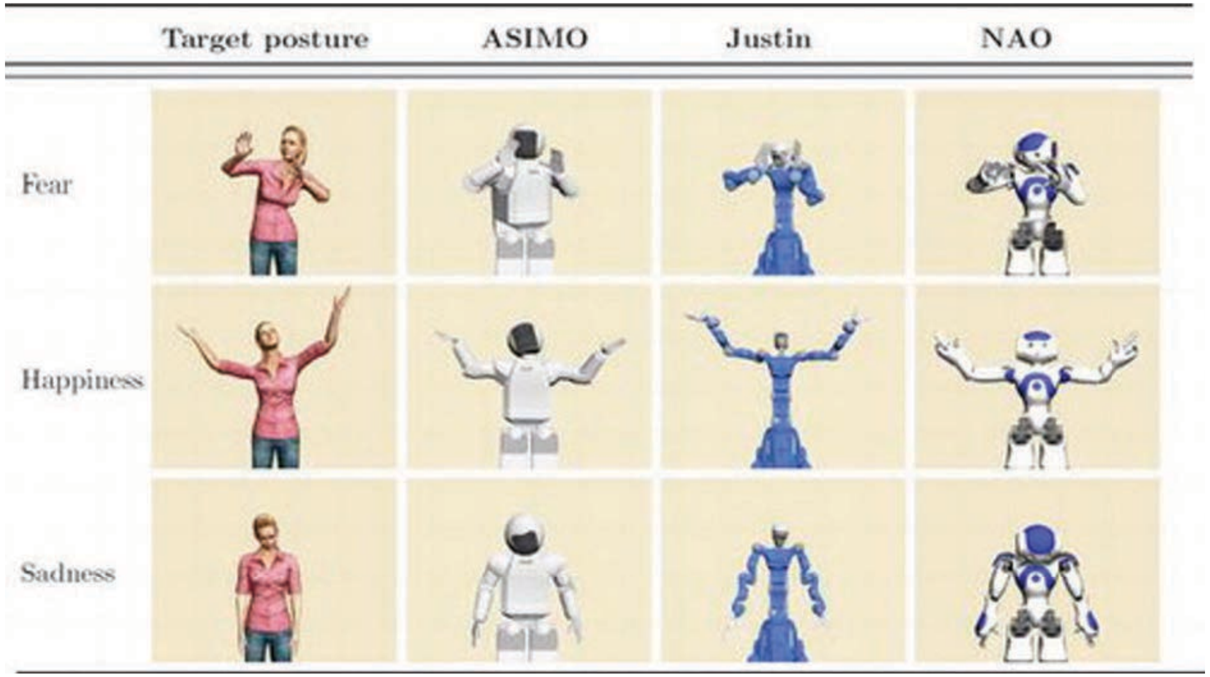
Generating Robot Gestures



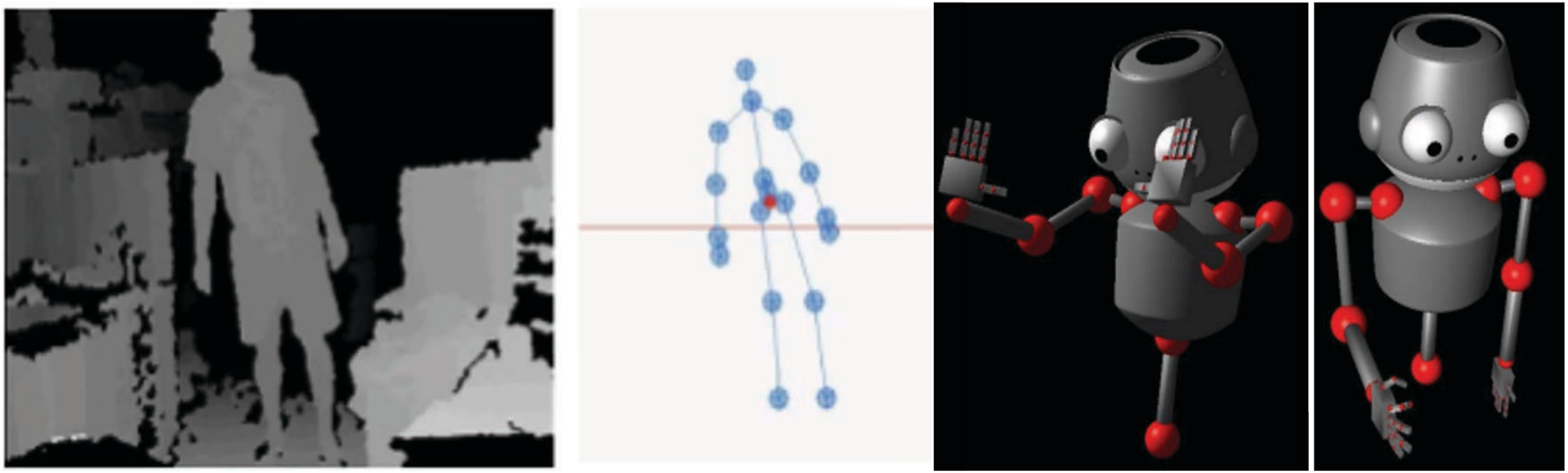




Deng, E. C., & Mataric, M. J. (2018). Generative Methods for Object-Based Gestures for Socially Interactive Robots.
Van de Perre, G., Van Damme, M., Lefeber, D., & Vanderborght, B. (2015). Development of a generic method to generate upper-body emotional expressions for different social robots. *Advanced Robotics*, *29*(9), 597-609.

Generating Robot Gestures for Non-Verbal Communication

Robotic Gesture Generation based on a Cognitive Basis for Non-Verbal Communication



Yang, J. Y., & Kwon, D. S. (2014, November). Robotic gesture generation based on a cognitive basis for non-verbal communication. In *2014 11th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI)* IEEE.

Humorous Robotic Behavior as a New Approach to Mitigating Social Awkwardness

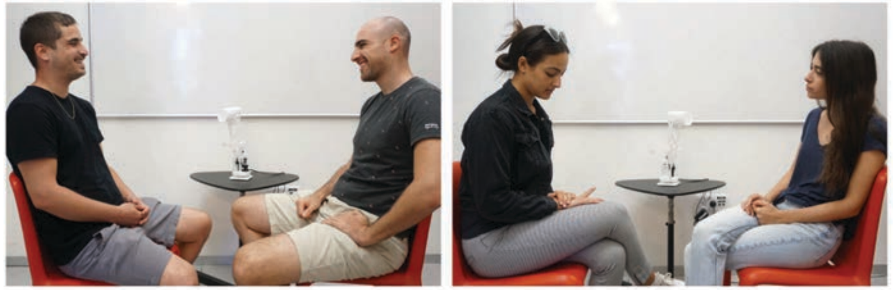


Figure 1: Two strangers interacting in this study's humorous condition (left) and in the non-humorous condition (right), used with permission [63, 116].

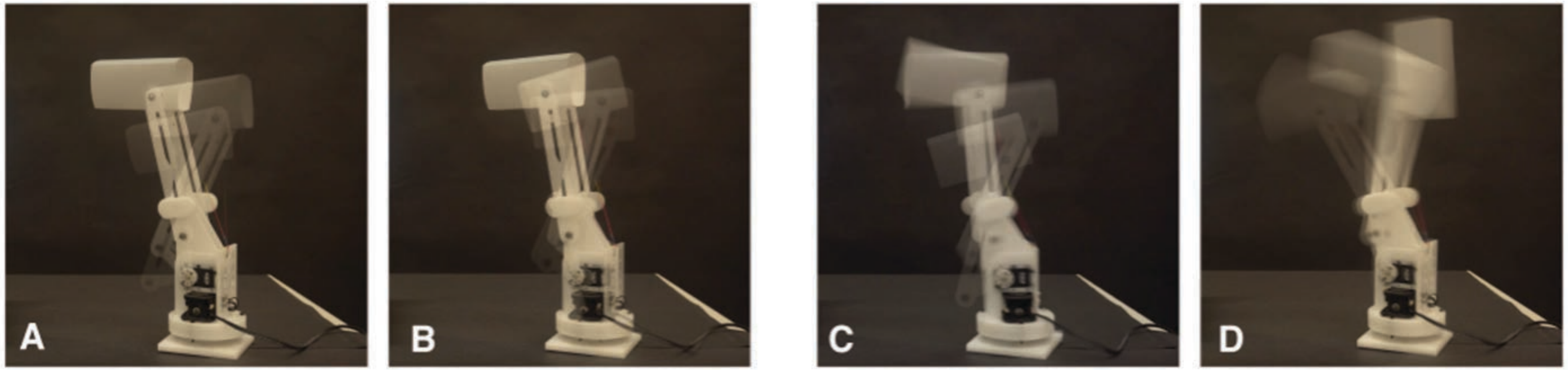
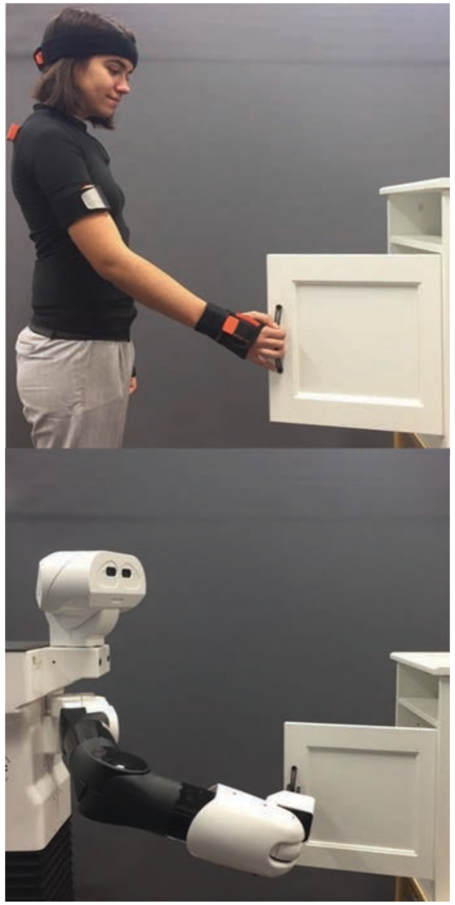


Figure 3: Robotic object performing non-humorous gestures (from left to right: A-Uprise Slow, B-Spark Neutral) and humorous gestures (C-Side Laugh, D-Spark Laugh), used with permission [63, 116].

Press, V. S., & Erel, H. (2023, April). Humorous Robotic Behavior as a New Approach to Mitigating Social Awkwardness. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-16).

Creating Understandable Robotic Expressions

How can we teach robots new tasks?



https://research.engineering.asu.edu/exploring-new-frontiers-in-human-robot-collaborations/
Arduengo, M., Colomé, A., Lobo-Prat, J., Sentis, L., & Torras, C. (2023). Gaussian-process-based robot learning from demonstration. *Journal of Ambient Intelligence and Humanized Computing*, 1-14.

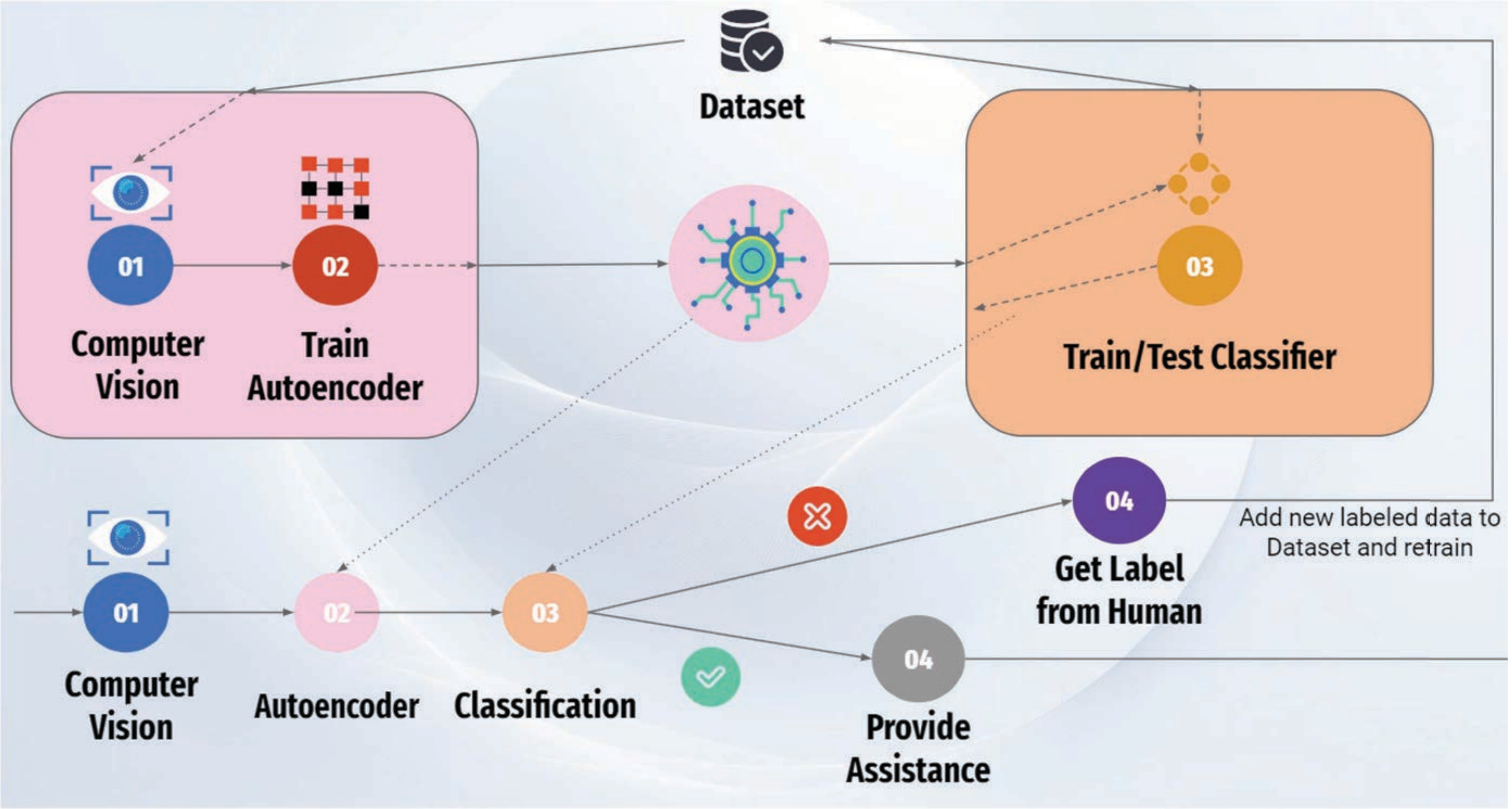
Robot Learning From Demonstration

Explainable Human-Robot Training

Wang, C., Belardinelli, A., Hasler, S., Stouraitis, T., Tanneberg, D., & Gienger, M. (2023, April). Explainable Human-Robot Training and Cooperation with Augmented Reality. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-5).

Making Robots Learn Implicitly

The Curious Robot



Investigating Opportunities for Active Smart Assistants to Initiate Interactions With Users

- When should the robot interrupt?
- How should the robot interrupt?
- How often should the robot ask questions?

Leusmann, J., Wiese, J., Ziarko, M., & Mayer, S. (2023, December). Investigating Opportunities for Active Smart Assistants to Initiate Interactions With Users. In *Proceedings of the 22nd International Conference on Mobile and Ubiquitous Multimedia* (pp. 495-498).

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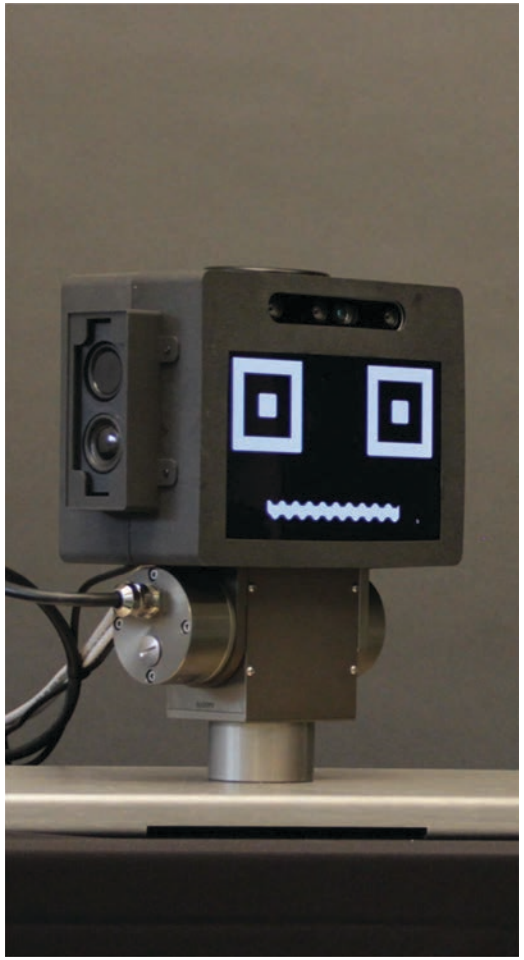
Human-Robot Collaboration



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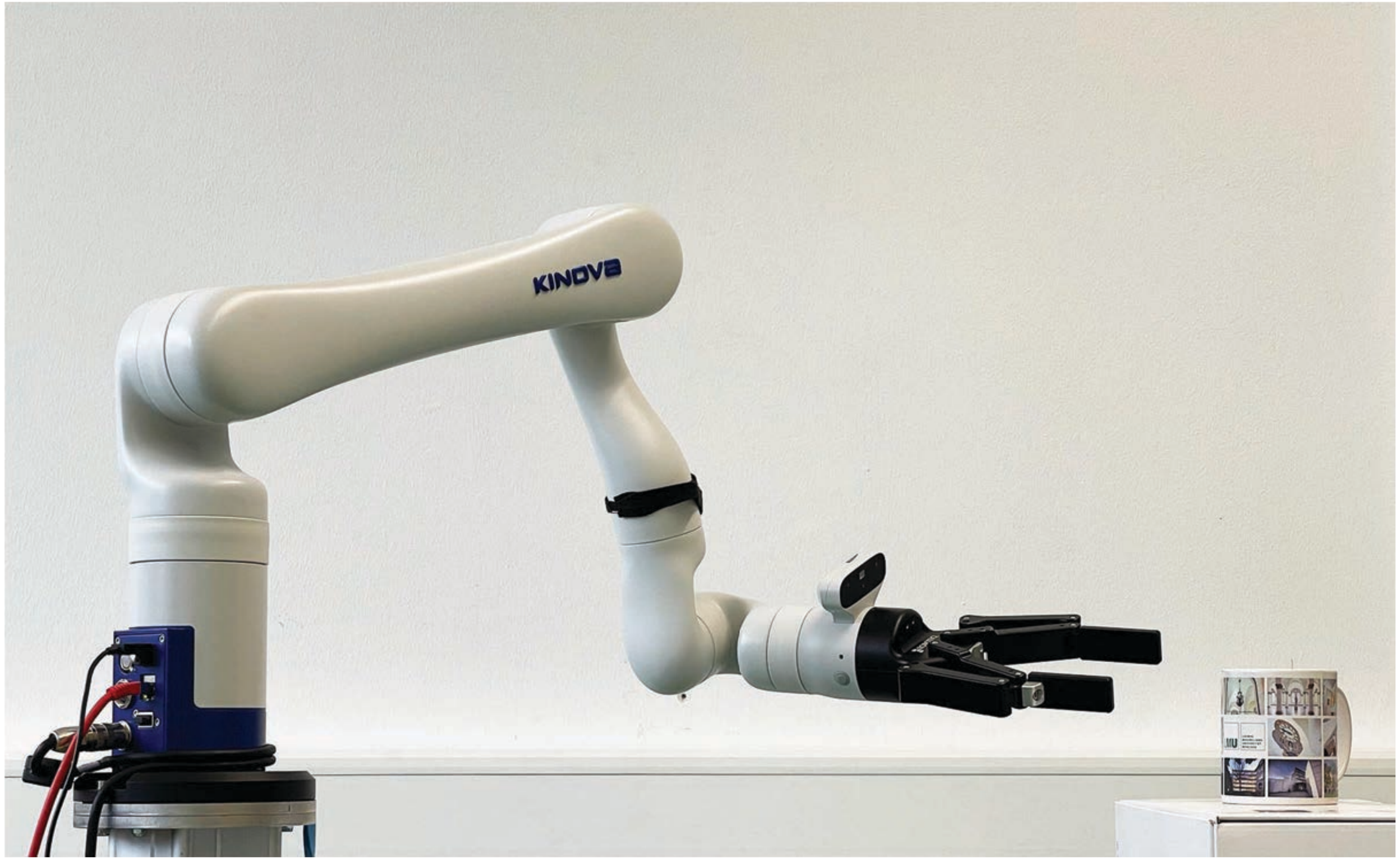
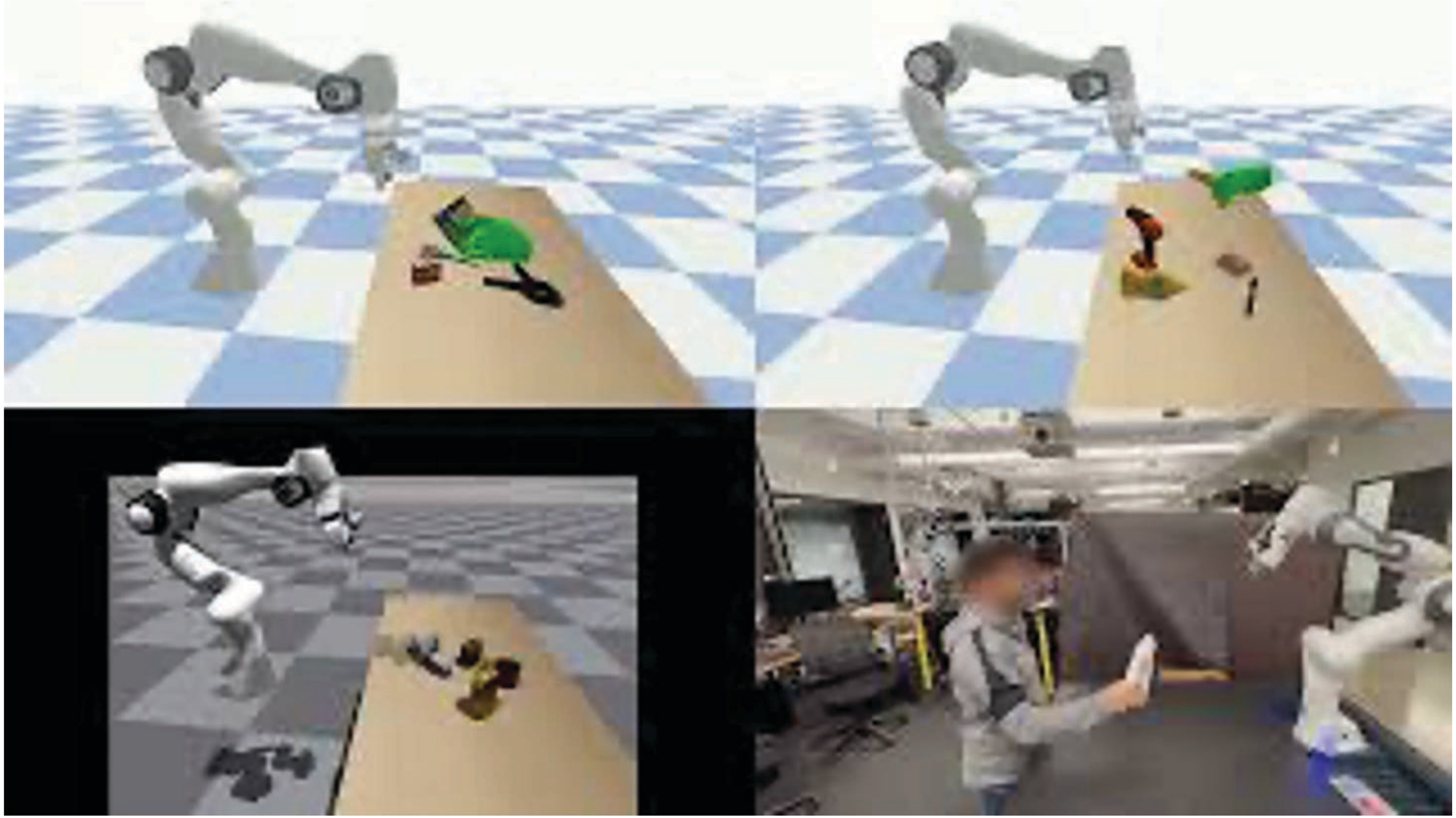


Human-Robot Handovers

- One of the most important tasks in Human-Robot Interaction as its needed for almost all collaborative tasks
- Technical Challenges:
  - How to grab objects?
  - How to hand over objects?
  - Tracking the human hand?
  - How to indicate different stages of the handover?
  - Properties of the objects?

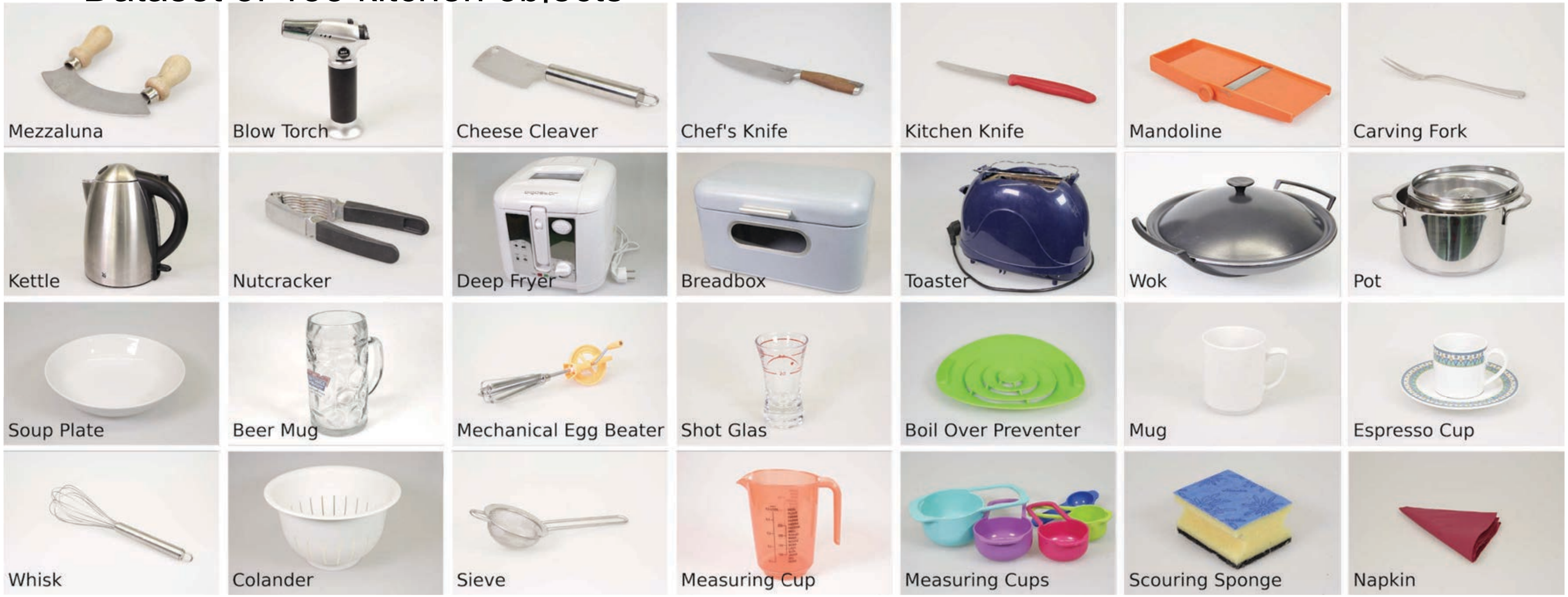
Learning Human-to-Robot Handovers from Point Clouds



Christen, S., Yang, W., Pérez-D'Arpino, C., Hilliges, O., Fox, D., & Chao, Y. W. (2023). Learning Human-to-Robot Handovers from Point Clouds. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 9654-9664).

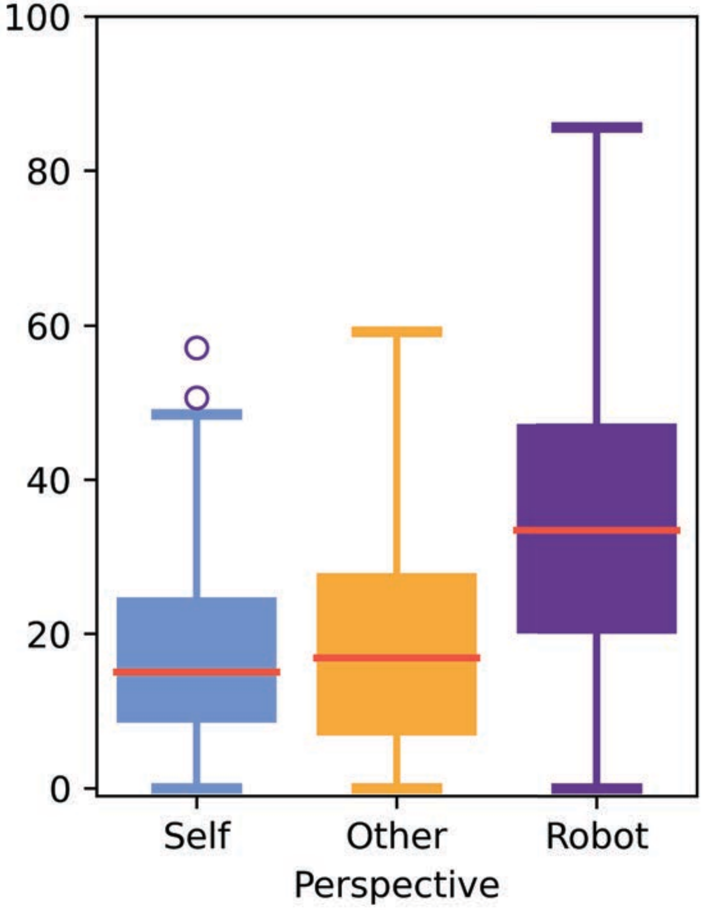
A Database for Kitchen Objects: Investigating Danger Perception in the Context of Human-Robot Interaction

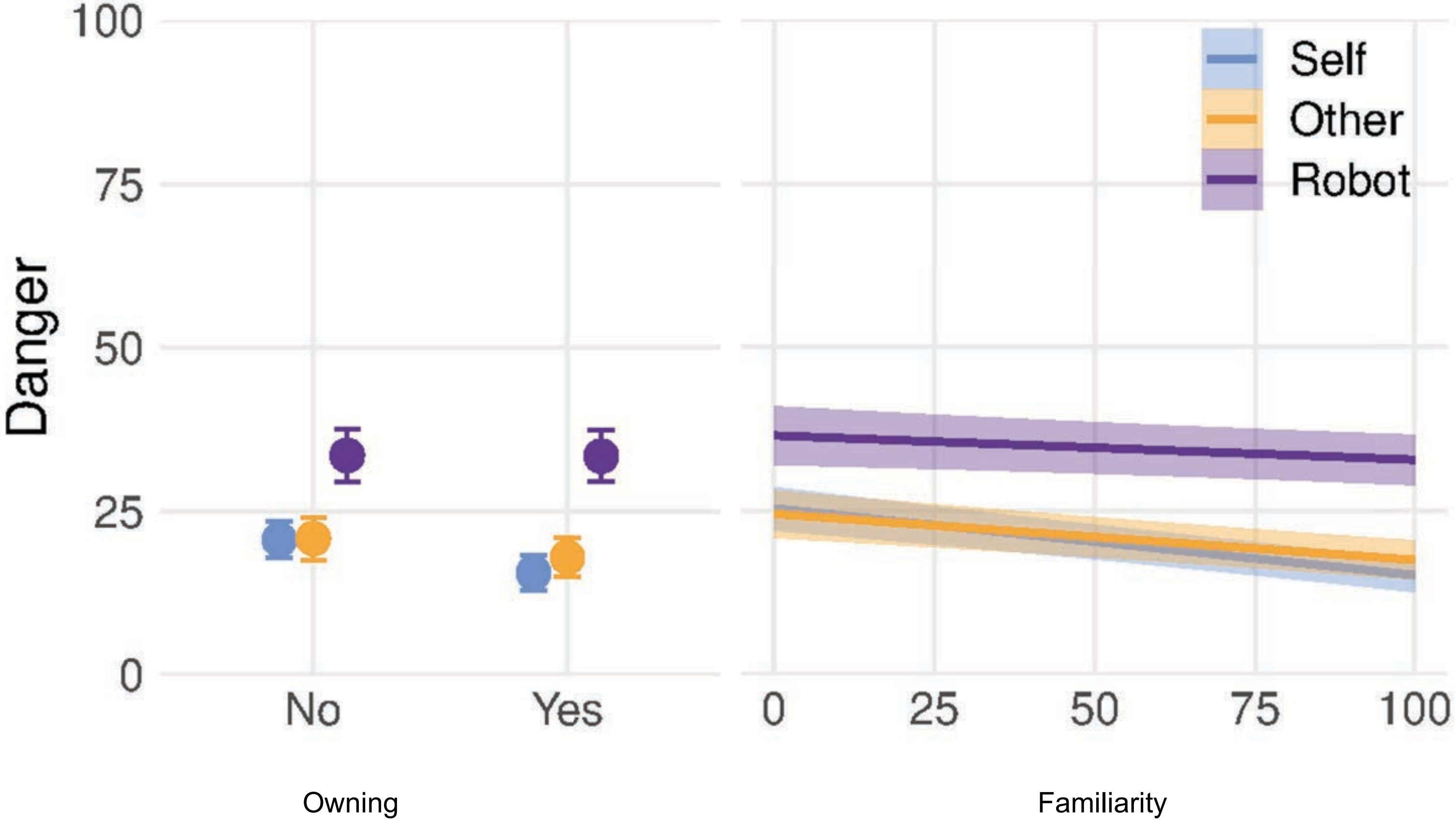
- Dataset of 153 kitchen objects



A Database for Kitchen Objects: Investigating Danger Perception in the Context of Human-Robot Interaction

Results





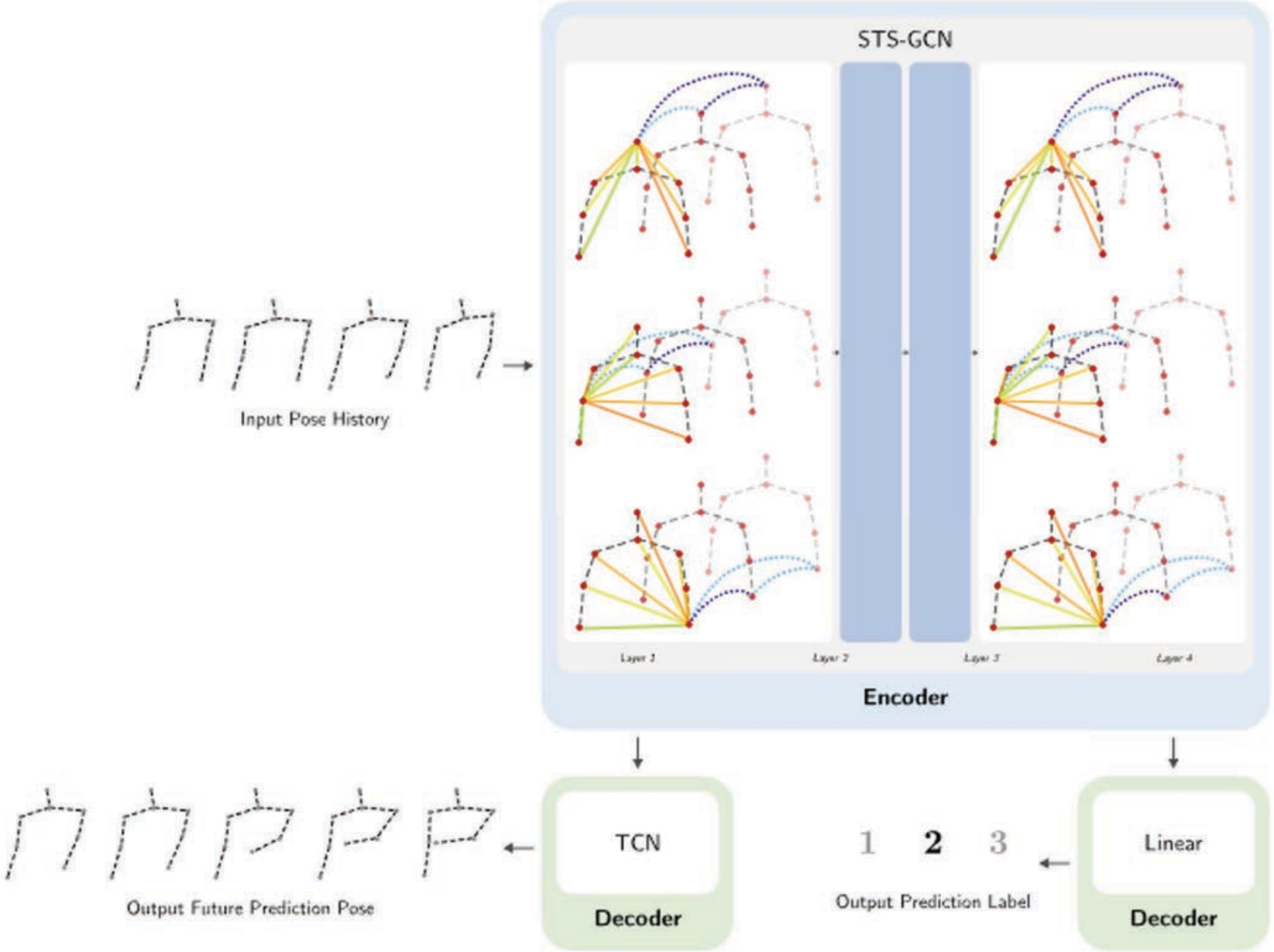
Timing in Human-Robot Handovers

Pan, M. K., Knoop, E., Bächer, M., & Niemeyer, G. (2019, November). Fast handovers with a robot character: Small sensorimotor delays improve perceived qualities. In *2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 6735-6741). IEEE.

Predictive Human-Robot Handovers

Motivation

- Goal: Figure out what timing humans prefer for the robot to start moving when the human hands over an object to the robot
- Prediction & classification model for human handovers based on human motion data
- 5 different conditions: very early detection, early detection, intermediate detection, late detection, very late detection



Predictive Human-Robot Handovers

Study

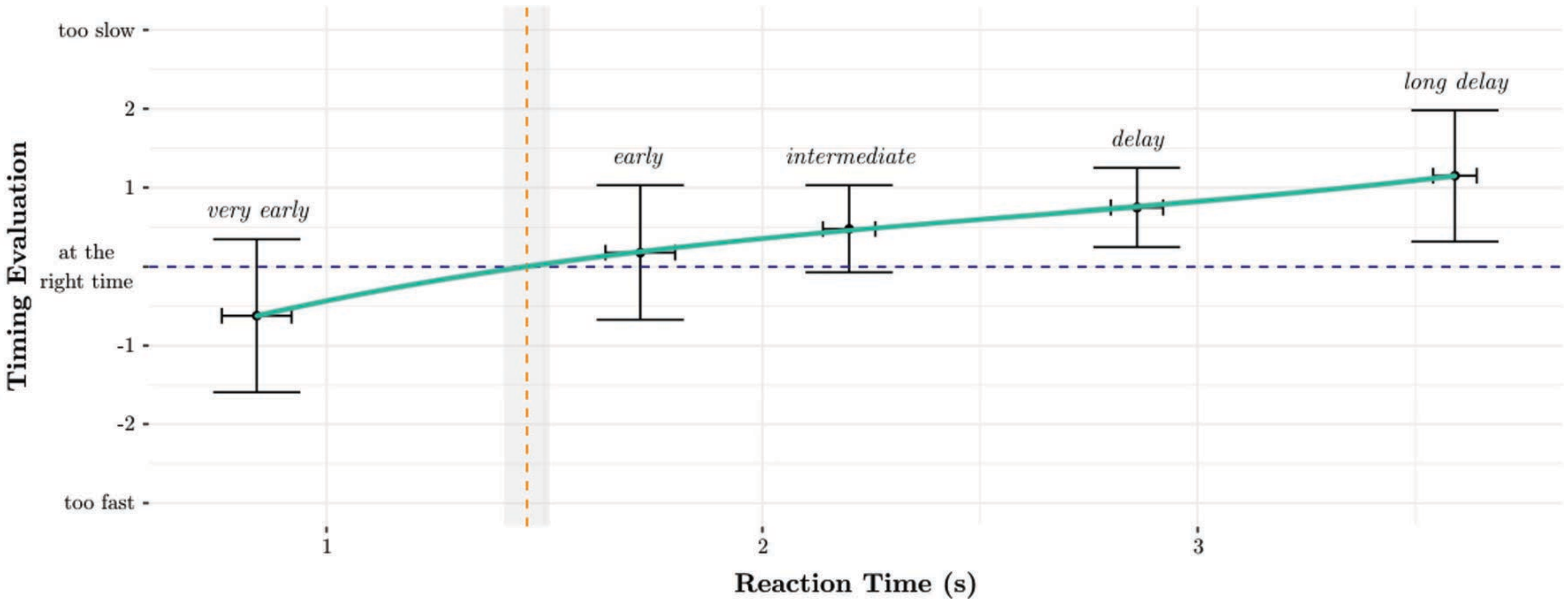
Delay

No Delay/Prediction

Prediction

Predictive Human-Robot Handovers

Results



Proxemics in HRI

Nonverbal Communication

- Facial expressions
- Gestures
- Paralinguistics
- Body language
- Proxemics or personal space
- Eye gaze, haptics (touch)
- Appearance
- Artifacts (objects and images)

Hall, Judith A., and Mark L. Knapp, eds. *Nonverbal communication*. Vol. 2. Walter de Gruyter, 2013.

Proxemics in HRI

Nonverbal Communication

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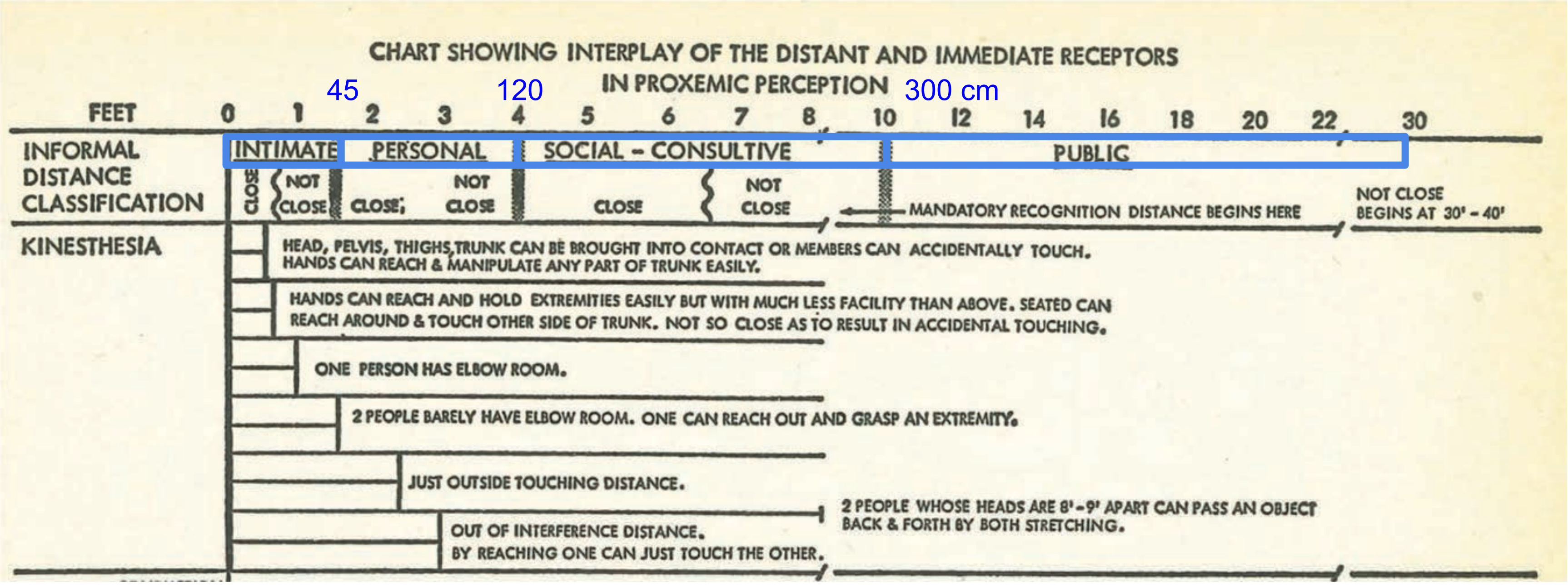
Hall, Judith A., and Mark L. Knapp, eds. *Nonverbal communication*. Vol. 2. Walter de Gruyter, 2013.

Proxemics in HRI

Origins

- The study of the cultural, behavioral, and sociological aspects of spatial distances between individuals.

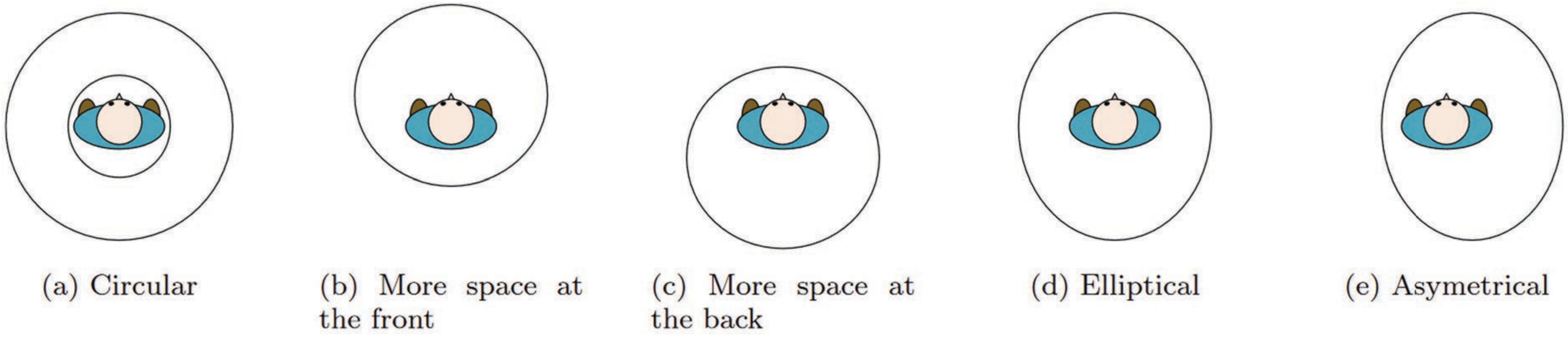


The American Heritage® Dictionary of the English Language, 5th Edition.

Edward Twitchell Hall. 1966. *The hidden dimension* (Anchor Books, 1990 ed.). Doubleday, New York.

Proxemics in HRI

Personal Space



Margot M. E. Neggers, Raymond H. Cuijpers, Peter A. M. Ruijten, and Wijnand A. IJsselsteijn. 2022. Determining Shape and Size of Personal Space of a Human when Passed by a Robot. *Int J of Soc Robotics* 14, 2 (March 2022), 561–572. https://doi.org/10.1007/s12369-021-00805-6

Proxemics in HRI

- Do we also need this for (non-humanoid) robots? → Yes
- Can we apply the same rules to robots? → 🤷‍♀️ possibly no
- Study Designs:
  - Robot approaches Human [1]
  - Human stops Robot [2]
  - Robot passes Human [3]
  - Robot crosses path with Human [4,5]
  - Robot hands over to Human

Matthias Luber, Luciano Spinello, Jens Silva, and Kai O. Arras. 2012. Socially-aware robot navigation: A learning approach. In *2012 IEEE/RSJ International Conference on Intelligent Robots and Systems*, October 2012, Vilamoura-Algarve, Portugal. IEEE, Vilamoura-Algarve, Portugal, 902–907. . https://doi.org/10.1109/IROS.2012.6385716

Proxemics in HRI

Validity of Results

[1] M.L. Walters, et al. 2005. The influence of subjects' personality traits on personal spatial zones in a human-robot interaction experiment. https://doi.org/10.1109/ROMAN.2005.1513803

[2] Elena Torta, et al. 2013. Design of a Parametric Model of Personal Space for Robotic Social Navigation. https://doi.org/10.1007/s12369-013-0188-9

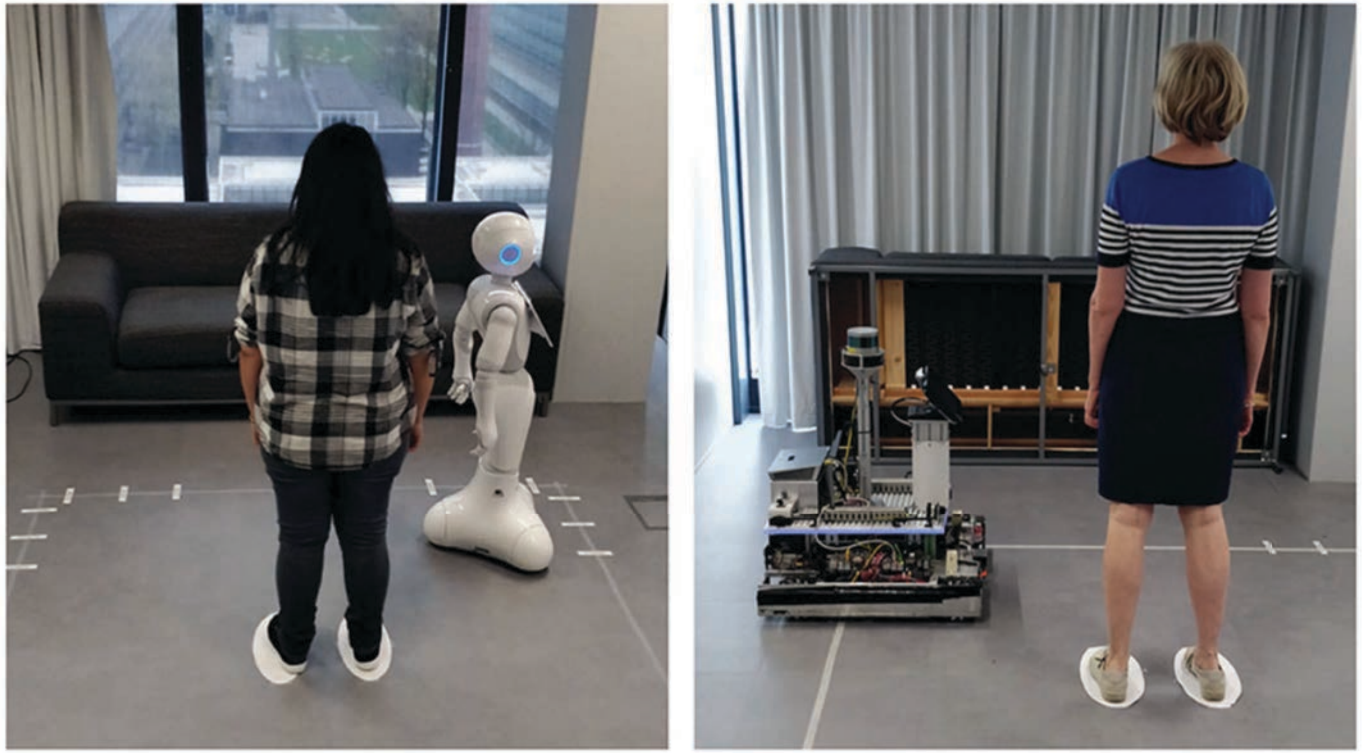
[3] Margot M. E. Neggers, et al. 2018. Comfortable Passing Distances for Robots. https://doi.org/10.1007/978-3-030-05204-1_42

[4] Christina Lichtenthaler,et al. 2013. Be a robot! Robot navigation patterns in a path crossing scenario. https://doi.org/10.1109/HRI.2013.6483561

[5] Shih-Yun Lo,et al. 2019. Perception of Pedestrian Avoidance Strategies of a Self-Balancing Mobile Robot. https://doi.org/10.1109/IROS40897.2019.8968191

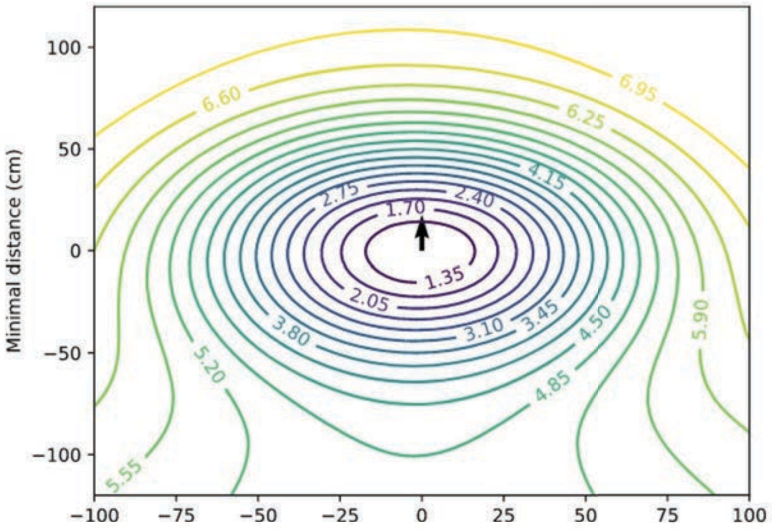
Proxemics in HRI

Influence of Anthropomorphism on User Comfort while Passing

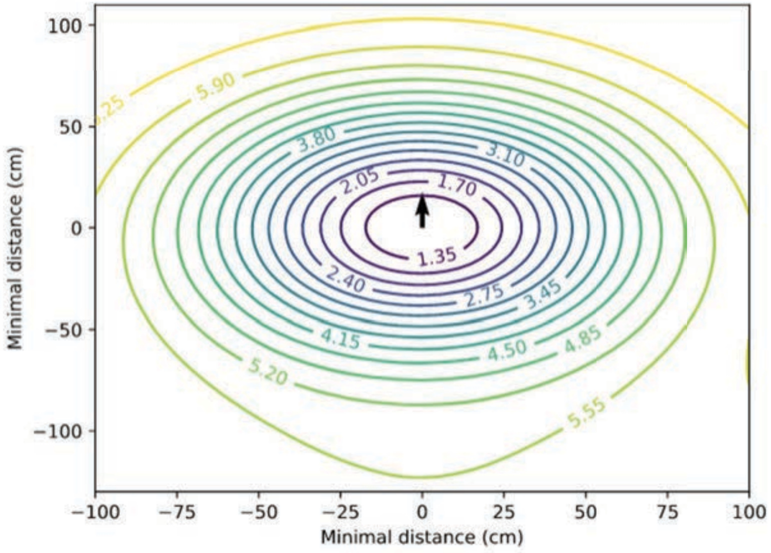


(a) Study A: Humanoid robot (b) Study B: Non-humanoid robot

(a)



(b)



Raymond H. Cuijpers, Peter A. M. Ruijten, and Wijnand A. IJsselsteijn. 2022. Determining Shape and Size of Personal Space of a Human when Passed by a Robot. *Int J of Soc Robotics* 14, 2 (March 2022), 561–572. https://doi.org/10.1007/s12369-021-00805-6

Proxemics in HRI

Validity of Results

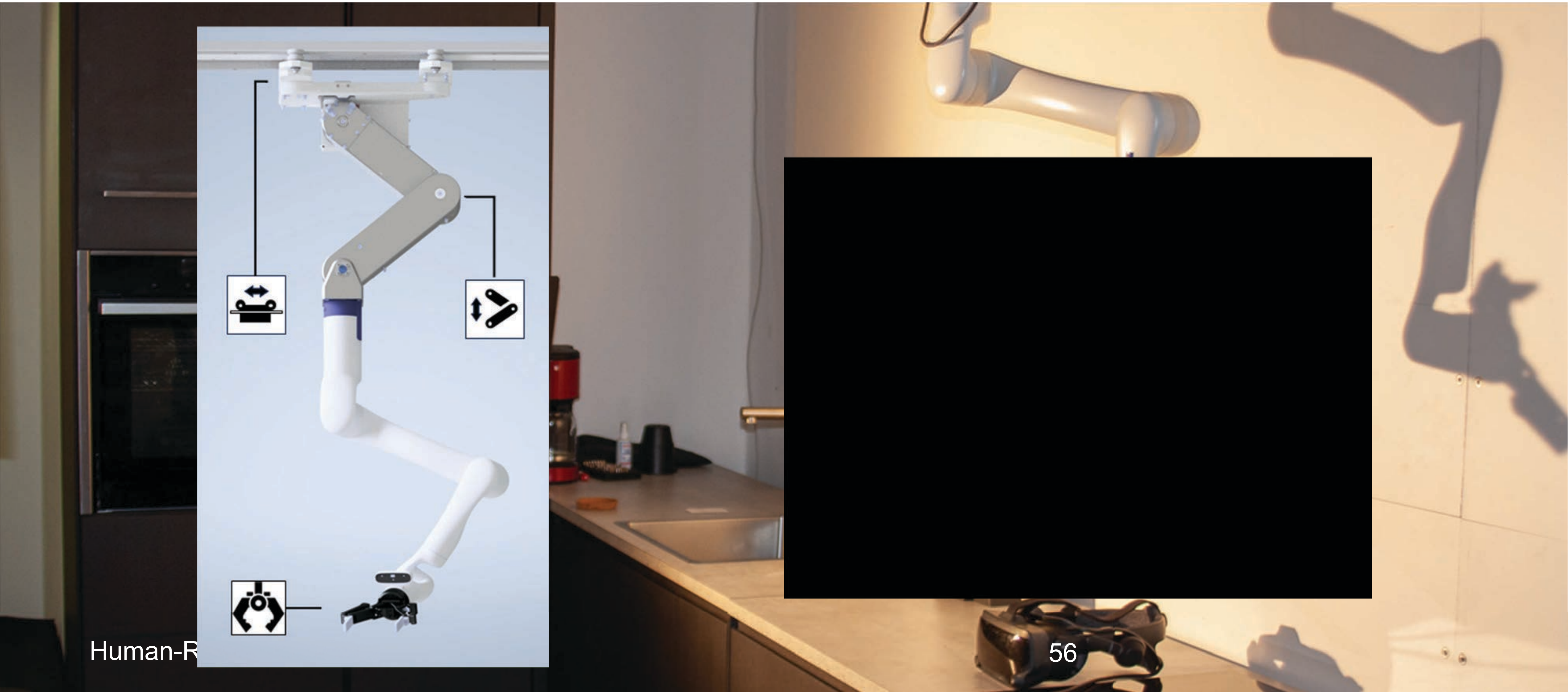
- Effects on User Comfort
  - Robot Appearance
  - Novelty Effect
  - Trust ← Predictability of Actions
  - (Laboratory) Setting
  - Type of Interaction
- Challenges
  - Reproducibility
  - Cost & Effort
  - Safety
  - Physics

Proxemics in HRI

Media Informatics Robot Lab

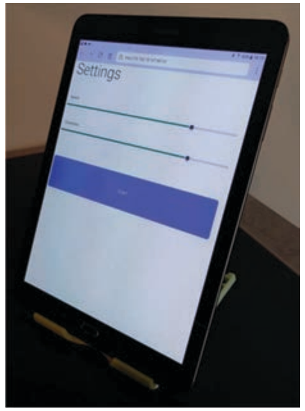
Proxemics in HRI

Media Informatics Robot Lab

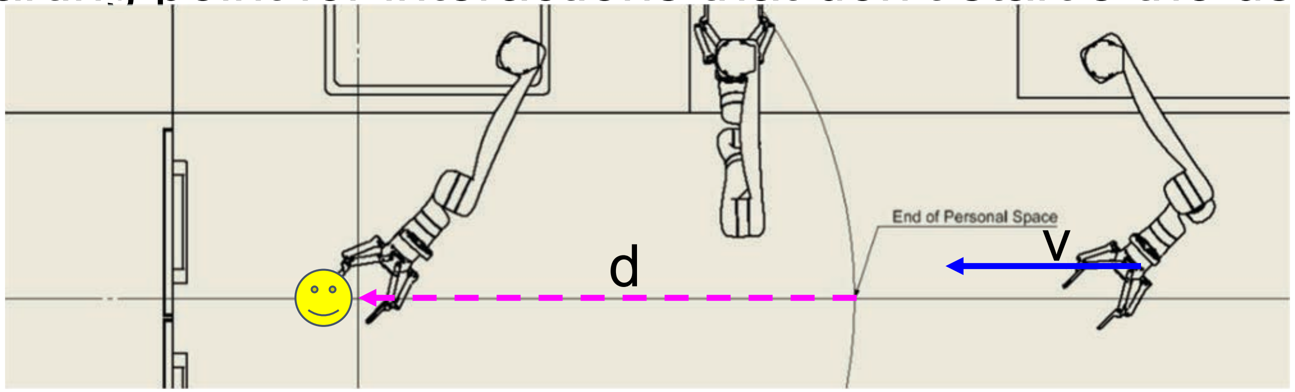


Proxemics in HRI

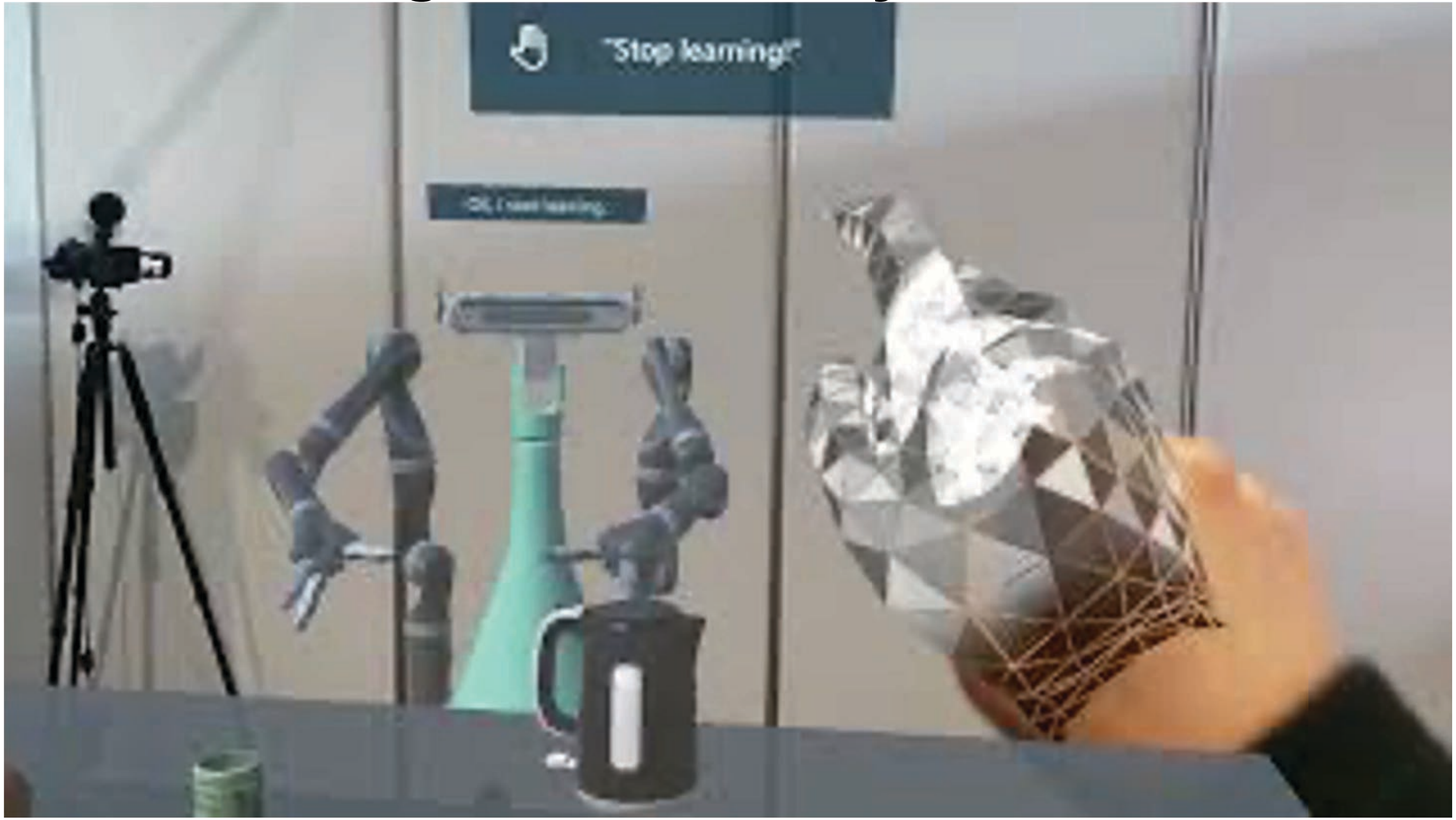
Investigating the effect of robot movement speed and velocity on user comfort and perceived danger during the handover of everyday kitchen objects



- User comfort depends on: context, speed, distance
- Approach the user with different objects, 3 of each group
- Let the user decide on speed v and handover distance d
- Goal: get average kinetic and proxemic settings depending on “danger index”, starting point for interactions that don’t startle the user

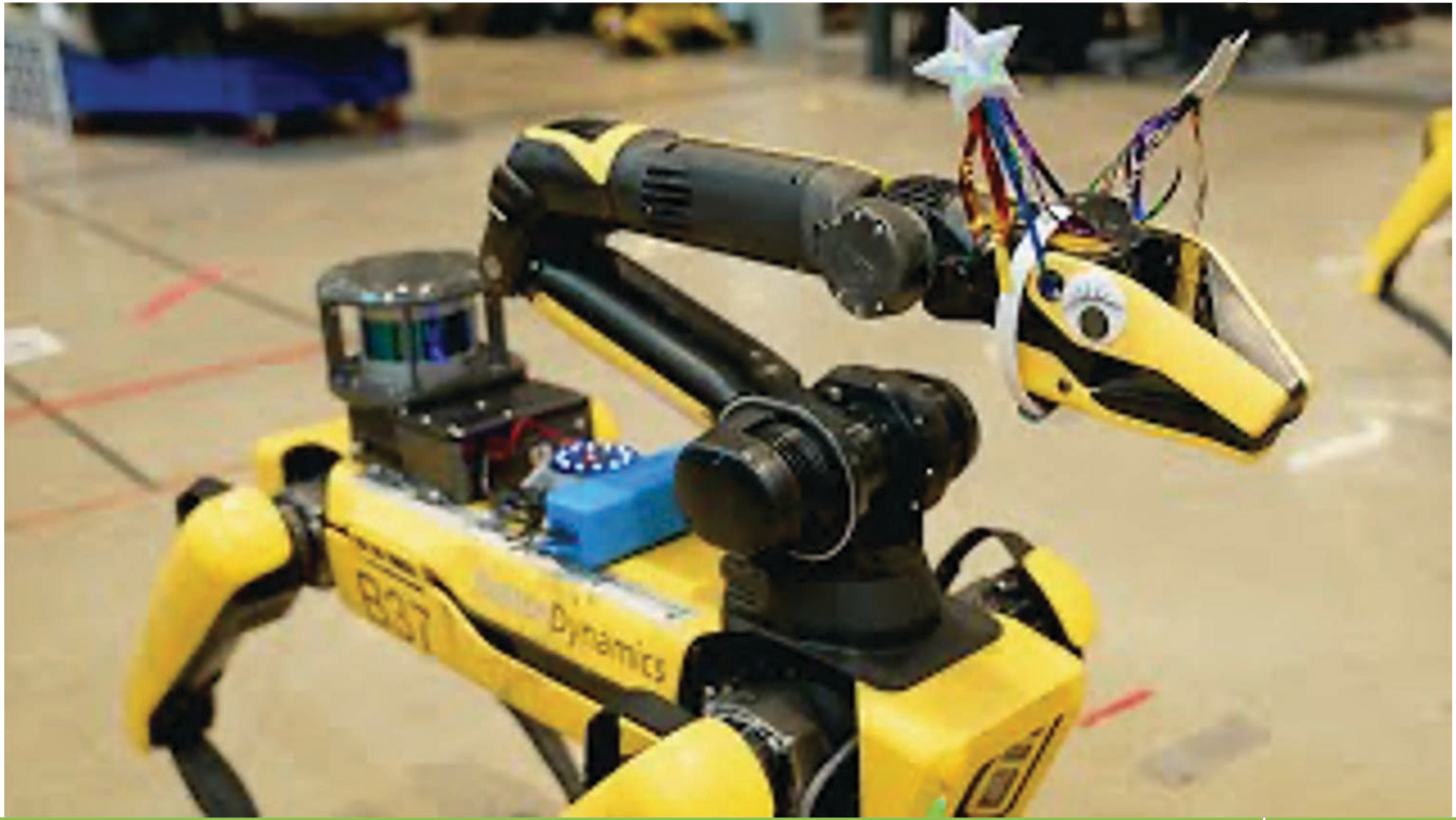


Communicating Robot’s Intentions while Assisting Users via Augmented Reality



Wang, C., Stouraitis, T., Belardinelli, A., Hasler, S., & Gienger, M. (2023). Communicating Robot's Intentions while Assisting Users via Augmented Reality. *arXiv preprint arXiv:2308.10552*.

LLMs + Robots



CoPAL: Corrective Planning of Robot Actions with Large Language Models

https://hri-eu.github.io/Loom/index.html

When are Robots coming to Households?

Conclusion

Human-Robot Interaction

- Application areas for HRI
- Anthropomorphism
- Robot gesture generation
- Human-robot collaboration
- Human-robot handovers
- Teaching robots: Robot learning from demonstration
- Visualizing robot intent
- LLMs + robots

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